REQ. NO. 1-9102

CONTRACT REPORT NO. OSQ81-00132

SURVEY OF REQUIREMENTS FOR PLATE STEEL IN OFFSHORE STRUCTURES AND ARCTIC VESSELS

FINAL REPORT

BY

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WORK ON THIS PROJECT WAS CONDUCTED UNDER THE AUSPICES OF THE CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY, ENERGY, MINES AND RESOURCES, CANADA.

DSS FILE NO : 14SQ.23440-1-9102
DSS CONTRACT SERIAL NO : OSQ81-00132
CANMET SCIENTIFIC AUTHORITY: DR. J.D. BOYD

128 pp

MAY, 1982

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EXECUTIVE SUMMARY

For several years, the Canadian offshore continental shelves on the East Coast, the Arctic Islands and the Beaufort Sea have been considered by the oil industry to be exciting geological plays. Offshore lease tracts are being negotiated and re-distributed among members of the industry who speculate on the presence of hydrocarbons in varying amounts based on results of seismic work.

Oil or gas have been found in promising or commercial quantities in both Canada's East Coast and the Arctic regions.

A similar development boom to that which the North Sea experienced a decade earlier is forecast for the Canadian East Coast, while the opening of the Beaufort Sea and the Arctic Islands to oil, gas and mineral developments promises Canada a significant technology position in Arctic transportation. However, Canada's environmental conditions in the geographical regions of interest are more severe than in any other area of the world where oil and gas has been explored for.

Energy, Mines and Resources, through its Canada Centre for Mineral and Energy Technology (CANMET), represented by the Physical Metallurgy Research Laboratories (PMRL) has recognized the need for early development or improvement of materials and fabrication technologies. To implement appropriate research and development programs, quantitative data on the material demands in terms of specifications and tonnages are needed to justify program expenditures.

PMRL contracted Chinook Fuel Innovations Ltd. to carry out this market survey and forecast to the year 2000 for thick steel plates of 25 mm and greater thickness. The pertinent survey used the approach of a critical evaluation of all planned projects to identify which are likely to be implemented during the forecasting period. An evaluation of current technology and assessment of future needs for all major hardware systems was then carried out for input into identification of thick steel plate needs for all equipment by project and year of plate order. Current and future material properties were identified and gaps in knowledge of such property needs were identified. Then, the ability of Canadian industry to actually meet the demand to the year 2000 in offshore structure fabrications and Arctic shipbuilding was evaluated. The work was concluded with suggestions for research and development programs to be carried out by PMRL and/or industry and/or public sector research organizations and recommendations to assist Canadian industry.

Based on numerous discussions with industry representatives of both users and fabricators, including representatives of the service industries, it was found that a considerably smaller number of projects and pertaining hardware systems - offshore structures and Arctic vessels - will be implemented during the forecasting period than optimistic industry announcements had led the public to believe, with consequently reduced thick steel plate requirements and subsequent reduction of demand on the Canadian supply industry. In addition, the existing gap between rules and regulations for design of offshore structures and Arctic vessels on one hand, and what industry and users know of the actual material property requirements for operation under extreme Canadian environmental conditions was identified.

Historically, offshore structures were built by shipyards. During the last decade though, several dedicated yards were established around the world for structures only. In Canada, the few offshore structures built - jack-up rigs and semi-submersible drilling rigs - were all built by shipyards.

It is considered very significant that one of the major findings of the overall evaluation of supply and demand was that the Canadian shipbuilding industry is heavily disadvantaged compared to its foreign competitors because of the ability of Canadian operators to import foreign built ships or foreign produced ship steels duty free, whereas the Canadian shipbuilders are levied high duty on ship outfitting equipment which they have to import for lack of Canadian equipment manufacturers. In addition, the majority of foreign ship suppliers are supported by their governments on export projects with varying forms of financing; a support the Canadian shipbuilders and fabricators are not provided with by the Canadian government for supply of products to Canadian buyers.

However, a smaller part of the Canadian shipbuilding industry is highly competitive internationally on small and medium size special vessels, e.g., ice-breakers. This is not the case for the Canadian steel industry, which produces a wide range of standard ship steels, but is non-competitive internationally in terms of price as well as in refined or modified steels, particularly for reduced sulphur levels. Both industries, the steelmakers as well as the vessel fabricators, are very cautious in gearing-up for the large demand increase promised by the oil industry. Their careful assessment of these demand forecasts is conditioned by the operators' procurement of the many support vessels from non-Canadian fabricators.

As for the total tonnage demand of thick steel plate - of 25 mm and thicker - the following is forecast in the three major steel grades for the entire forecasting period:

- *Steel Grade E = 42,260 tonnes;*
- *Steel Grade EH36, including EH modified = 192,250 tonnes;*
- *Low Temperature Steel = 146,485 tonnes.*

Broken down by thickness ranges:

- *the 25-37 mm range = 223,080 tonnes; and,*
- *thicker than 38 mm = 157,915 tonnes.*

To provide the Canadian shipbuilding industry a higher degree of opportunity in bidding against foreign competitors for Canadian ships requires a substantially remodelled financial aid package to include, primarily, a short term low interest loan for the duration of the construction period. To position Canada at the top of international technology for low temperature or Arctic structures and vessels, establishment of a comprehensive cold regions data bank is necessary. These data would be accessed by all interested parties - steelmakers, shipbuilders and fabricators, naval architects, designers and engineers, project operators, equipment manufacturers and service firms.

Overall, Canada's industries participating in offshore structures and Arctic vessels development, construction and operation have substantial opportunities before them, but also challenges which can likely be mastered only through joint efforts including the Government of Canada.

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ACKNOWLEDGEMENTS

Chinook Fuel Innovations Ltd. would like to express appreciation to Dr. R. Thomson of CANMET and to Ms. M. Brock of Supply and Services Canada for their assistance in obtaining Government of Canada sponsorship of this survey and forecast and to the Scientific Authority, Dr. J.D. Boyd for his capable guidance and assistance during the project.

Appreciation is also tendered to the many representatives of the Canadian fabrication industry, of the steelmakers and of the user companies for both their interest during the study and their assistance in supplying information relative to the work.

Thanks are extended also to German & Milne, Inc. for a study on thick steel plate requirements for Arctic ships prepared for Chinook Fuel Innovations Ltd.

1. INTRODUCTION

Several large projects were announced over the past few years for exploitation of Arctic and offshore hydrocarbon resources. Massive investments to finance these mega-projects were identified as competition to other alternative hydrocarbon developments.

The magnitude of these projects as well as the degree of uncertainty of their timing is overwhelming. While some of the technology is available in Canada, most of it will need to be imported. In addition, new technology must be developed for certain areas.

If the ability to supply material, equipment and services domestically is to be maximized, significant planning procedures including development of technology are to be instituted. The Physical Metallurgy Research Laboratories of Energy, Mines and Resources Canada, (CANMET) have recognized the need to develop an overview of the demand and supply situation to the year 2000, particularly on:

i) tonnage of 25 mm plate and thicker;
ii) the material grade distribution;
iii) special high strength steel;
iv) preferable material properties;
v) gaps in fabrication technology;
vi) research and development requirements;
vii) Canadian steel supply capability;
viii) Canadian capability of fabricating structures and ships.

PMRL have commissioned this survey and forecast from Chinook Fuel Innovations Ltd., who have the required qualifications to carry out this work.

This report is structured to lead through an outline of announced projects to a technology section including material properties and to steel plate demand analysis. The analysis of capabilities follows, with research and development suggestions completing the report.

Immediately following the Introduction are the Terms of Reference in Section 2; Conclusions in Section 3 and Recommendations in Section 4.

Section 5 outlines the methodology used to carry out this work and the sources utilized for the gathering of data and information.

Section 6 gives an overview of the Energy Market Development Framework, while critical analysis of the announced projects for the offshore and Arctic areas and their potential for implementation are discussed in Section 7.

Section 8 is devoted to the technical issues, beginning with the environmental conditions in frontier areas by geographic area, followed by a description and definition of exploration and production system categories.

Section 9 discusses the current and future material property requirements.

Section 10 contains the demand analysis for thick wall steel plate by project area and year of plate orders. Instead of using sensitivities to identify optimistic and pessimistic cases, the demand is shown per project.

The Canadian supply capability is discussed for steelmaking and fabrication in Section 11.

In Section 12, suggestions for research and development are identified.

Appendices provide additional back-up information on systems technology and details on thick steel plate demand.

2. TERMS OF REFERENCE

The broadly scoped spectrum of this work ranged from survey to technology forecasting, calling for the use of several tools. The work statement and tasks overview is repeated below.

WORK STATEMENT

An extensive survey will be made of projected future plate steel requirements for offshore structures and Arctic vessels. For each application, both the amount of steel required and the property specifications will be considered. Technology barriers which limit Canadian production of the required plate products will be identified, and appropriate research problems will be delineated. Information for this study will be obtained through contacts with suppliers of plate steel products in Canada and with oil companies operating in Canada and abroad.

TASKS OVERVIEW

TASK I - Survey of Current and Forecast to 1990 and 2000 of offshore structures and Arctic vessels types, sizes and amounts.

TASK II - Identification of thick plate (>1") requirements in current and future structures and vessels by specification, fabrication, use and amount.

TASK III - Evaluation of the capabilities of Canadian manufacturers and fabricators to meet the needs identified in Task II.

TASK IV - Identification of technology barriers and discussion of relevant research problems.

3. CONCLUSIONS

A large number of oil and gas projects in Canada's offshore and Arctic areas were forecast by industry in the recent past. In the seven major geographical regions a total of nine project areas are identified.

For these project areas, and distributed over the forecasting period, a total of 185 major pieces of equipment in twelve equipment categories will be required. These categories include:

- supply boats;
- drilling semi-submersibles;
- production or processing semi-submersibles;
- storage semi-submersibles;
- oil tankers;
- LNG tankers;
- steel jacket platforms;
- barges;
- steel caissons;
- round drillships;
- ice-breakers; and,
- dredges.

This equipment will require thick steel plate amounting to almost 400,000 tonnes. Distributed by steel grade, it breaks down to:

42,260 tonnes of Grade E;
192,250 tonnes of EH36 (including EH Modified);
146,485 tonnes of Low Temperature Steel;

or by thickness range:

223,080 tonnes for 25-37 mm;
157,915 tonnes for over 38 mm.

Although the thinner steel plate requirements, which are likely an order of magnitude larger, are not included in the above figures, a higher thick steel tonnage could have been expected based on oil industry announcements, Some of these, however, were unreasonably optimistic.

Few floating drilling rigs will be newly built, for the current rig availability rate is expected to increase. Therefore, at best, some of the existing rigs will be upgraded for application in harsh Canadian conditions.

Even though at reduced overall requirements, that equipment will be needed in large quantities which Canadian shipyards can construct best - relatively small supply boats: 55 units; barges: 51 units, (for storage, processing equipment, accommodation, construction and operation); and 18 ice-breakers. Large oil tankers could amount to 22 if no pipeline transportation of Beaufort Sea oil is used.

Canada's major steelmakers may be interested in serving the market with improved cold temperature steels only if:

i) the Canadian market becomes large enough to warrant investment into steelmaking equipment already available to Japanese and European steelmakers;

ii) the material property requirements are below what foreign suppliers delivery already free of extra cost, e.g., sulphur content an order of magnitude below specs; and,

iii) the level of entrepreneurial risk is below what the international competition is accepting.

It appears therefore that the Canadian builders of offshore structures and ships will continue to use improved ship steels from foreign sources.

A few Canadian shipyards are progressively managed and meet international standards by quality and capability, if not by scale. But already now, the Canadian labour cost is about 25 to 40% higher than international levels and Canadian steel prices exceed the superior Japanese steels by about 12 to 20%. In addition, for certain structures and vessels, the international competition has a proven record in technological innovation and, consequently, in product quality and cost efficiency.

There is a trend towards specialization developing in the international ship and rig building industry:

- Korean firms offer the lowest price in labour and steels; while,
- Japanese companies concentrate more on high quality, particularly in steels, but also in workmanship;
- Japanese yards are also planning to increase automation in production by using domestic experience in industrial robotics.

For exporting their products, many foreign competitors are provided with low interest financing by their governments, whereas the Canadian fabricators get no assistance when producing for Canadian firms. In addition, foreign-built ships and semi-submersibles can be imported with no duty levied, while ship or rig outfitting equipment must be bought almost exclusively outside of Canada at full custom duty.

All of these factors contribute to cause offshore rig and vessel operators to continue purchasing overseas.

The major opportunity for the currently less efficient shipyards is in progressive upgrading of facilities, skills and marketing, to be prepared for subcontract work from the larger Canadian or international yards.

An increase of productivity through welding by automation offers substantial room for improvement in Canadian yards. While most of the welding technology and automated welding systems are available internationally, many Canadian shipbuilders will have to acquire new machines and increase the level of skill of shop personnel in order to become competitive.

Independent of material demands and shipbuilding progress, the status of knowledge of material property requirements for Arctic service is insufficient. A necessity for the Canadian industry for offshore structures and Arctic vessels is the availability of and access to a data base of material properties for design and engineering, construction and installation, operation, maintenance and repair of equipment to serve in the Arctic and environmentally severe offshore regions.

4. RECOMMENDATIONS

Maximum benefit for Canada and the industries involved in the building of offshore structures and Arctic vessels can only be achieved if these industries become more competitive.

Winning of most of the contracts from Canadian purchasers will substantially improve the balance of payments. However, such a substantial improvement in overall competitiveness needs a mix of changes which would involve:

- the Government of Canada providing an improved fiscal scheme;
- the operating industry, regulatory authorities, including certification/classification societies and the research and development community assisting the establishment of a data bank of engineering and material properties for equipment in cold regions; and,
- the builders/fabricators adapting to modern international standards in overall capability including quality, skills, cost effectiveness and, to some extent, size.

Although the fiscal regime under which the industry competes for jobs is beyond the scope of this survey it has become apparent that substantial improvement is necessary.

For the enhanced understanding of material property requirements, the following is recommended:

- Development of a data bank as basis for a Code of Practice for cold region projects to include data for design, engineering, fabrication/construction. operation, maintenance and repair. This activity should be carried out jointly by industry, governments, regulatory authorities, classification societies and the research and development community. This data bank should then be made accessible to all interested parties.

- It is further recommended that a maximum plate thickness for critical regions is established and test series conducted for toughness at temperatures to -80°C using existing medium and low temperature steels and varying compositions (S,N,Ni, etc). These tests should include Charpy Impact tests, fracture mechanics, formability, weldability, fatigue, corrosion resistance and through-thickness ductility and would form the basis for the Code of Practice. Specifically, for application in Arctic vessels, the following must be done to ensure adequate safety standards for future hull structure requirements:

  i) Impact induced stresses must be analysed and included in the strength criteria.
  ii) Failure from fatigue induced by ice dynamic loading should be analysed and included in the strength and material properties criteria.
  iii) Brittle fracture phenomena related to heavy impact loads with very short rise time should be analysed and included in the strength and material properties criteria.

A modernization of the currently lesser successful yards is urgently recommended to permit them to participate in the increasing domestic market, particularly for subcontracts of small but specialized ships and of modules of offshore structures and large ships. It is therefore recommended that a joint industry/government funded fabrication technology evaluation be conducted to identify, for current and anticipated rig and vessel designs, the most cost effective fabrication methods and procedures. This would include the following major areas of operation:

- yard organization, including material flow, fabrication steps, etc;
- metal forming;
- fit-up and jigging;
- welding;
- sizing of machinery/hulls/docks/yards to meet the increasing sizes of modules of the new vessels and rigs;
- degree of automation;
- committment to quality of workmanship and product.

Subsequent to the general study, direct advice should be given to participating yards considering their specific line of business.

The benefits for many of the smaller yards and firms who are less aggressively marketing, would be in an increased position of competitiveness and a more realistic identification of areas of specialization in which the yard could concentrate.

5. SURVEY & FORECAST METHODOLOGY

To fully satisfy the scope of work, the study required a diversified approach which included several quite different functions:

- survey of market;
- forecast of market developments;
- evaluation of domestic capability;
- evaluation of existing technology and forecasting of future developments;
- design input into technology forecasting;
- assessment of industrial benefits.

For the gathering of data and collection of information, various approaches were used:

a) published literature -
  . journals;
  . trade magazines;
  . business/financial papers;
  . conferences (or proceedings);
b) interviews with -
  . operating companies;
  . project sponsors;
  . steelmakers;
  . naval architects, engineers and fabricators;
c) use of internal files;
d) interpretation, evaluation and development of data based on information from various sources.

On the basis of announced projects by project sponsors, a critical assessment was made regarding their technological maturity, timing, material requirements, policy scenarios, economic benefits and other criteria.

Based on these evaluations, reasonable development scenarios of offshore/Arctic oil and gas development activities were forecast. They included a listing of projects likely to be developed during the forecasting period. Following that, a calendar of systems, vessels and structures categorized by representative type, size, capacity and timing was developed.

The forecast for natural gas development, including liquefied natural gas (LNG) projects in the Arctic and East Coast was approached differently than that for crude oil because of the likelihood that some projects are influenced by political factors more than economic ones.

The technical and operational requirements for each potential system were identified. Then, the existing relevant technologies from applications in other countries were assessed in relation to the environmental requirements for each of the geographical areas. Extrapolation of technology was used for areas where current technology is unsuitable and the technological development was predicted for application in areas where no technology has been available to date.

The scope of permit issuance and interpretation of codes, standards and recommended practice by certifying bodies were interpreted for current requirements and the adequacy of such requirements for next generation technology or novel technology developments evaluated. This included both material properties and welding.

The analysis was then carried out based on the market and technical data per representative exploration/production/transportation system or size. To identify procurement timing of steel plate demand, a calendar of plate purchase orders was developed. Thus, the thick steel plate demand is variable by project expectation.

Independent of the thick steel plate demand, the following criteria were evaluated:

- material property requirements;
- fabrication technology;
- capability of domestic steel manufacturers;
- Canadian fabrication capability;
- technological barriers;
- research and development requirements.

6. ENERGY MARKET DEVELOPMENT FRAMEWORK

6.1 BACKGROUND

To date in Canada, no oil or gas is produced from any of the offshore areas. Many discoveries have been made, some of commercial quantities, e.g., Hibernia. Therefore, exploration is continuing strong in the Beaufort Sea, the Arctic Islands (most recent discovery - Cisco C-42 well) and off the East Coast. Plans for the commercial exploitation are being prepared, while the guessing on the jurisdictional dispute between Canada and Newfoundland continues.

The supply of natural gas is not considered critical to Canada's energy demand and supply balance, as a 30 year supply is assured; governments and industry promote the increased use of natural gas in new markets.

6.2 CANADIAN ENERGY DEMAND FORECAST

During the year 1981, several major events occured which changed the Canadian energy scenario. In June, 1981, the National Energy Board issued its "Canadian Energy, Supply & Demand, 1980-2000" report (National Energy Board, 1981), which is based on the statements and forecasts of the major energy companies in Canada. Because of the comprehensive evaluation and the detail of data forecast, this report is considered the most appropriate source of information for the purpose of this study. Most of the submissions then provided to the NEB suffered from the after-shock of the introduction of the National Energy Program of October, 1980; this program had caused a general downturn of expectations of the energy industry for future synthetic fuel production.

Another significant event, the signing of the Energy Pricing Agreement of September 1, 1981, between Ottawa and Alberta would have had the effect of encouraging several energy projects, had the world oil price continued along an upward tending path. However, the dramatic downturn in the oil price during the latter part of 1981 and, particularly, the first quarter of 1982, likely wiped out most of the advantages of the Energy Pricing Agreement.

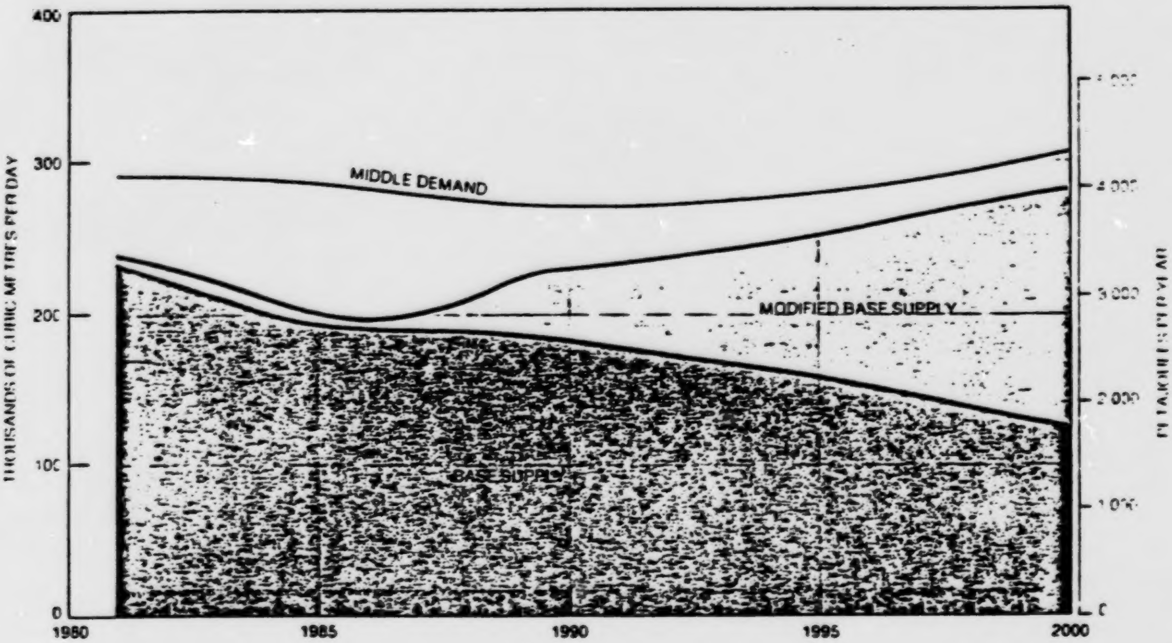
It is therefore concluded that base case demand of oil and equivalent and the supply as identified by the NEB in its report are a reasonable basis for the current forecast. Figure 6-1 represents the NEB's forecast on supply and demand - crude oil and equivalent base case supply with middle demand. The base supply includes the currently established reserves for light crude oil and the expected reserve additions, plus pentanes and some oil sands production in addition to some frontier production and upgraded heavy oil.

The development of the world oil price is the single most important factor relating to the Canadian self-sufficiency in crude oil. It is already the case in Canada that import-subsidy-based heavy oil is more economical for eastern refineries than Canadian produced heavy oil. If the world oil market price for light oil drops further, it will render Canadian new oil (new oil reference price) uneconomic.

FIGURE 6-1

SUPPLY & DEMAND-CRUDE OIL & EQUIVALENT

BASE AND MODIFIED BASE SUPPLY WITH MIDDLE DEMAND



SOURCE:. National Energy Board (1981).

For the purpose of this forecast, it is assumed that the current drop in world oil price is more of an upset than the establishment of a new trend; also that self-sufficiency in crude oil or equivalent is reached in Canada by 1995. While under the impression of the NEP, most of the submitters to NEB's 1981 hearing were rather divided as to the possibility of reaching self-sufficiency before the year 2000, it is assumed here simply for the good economic sense it would make to stimulate Canadian industry rather than that of OPEC countries.

It follows then, that the current level of crude oil or equivalent imports increases from 55,000 cubic meters per day to about 88,000 cubic meters per day by about 1985 with subsequent reduction to about 85,000 cubic meters per day in 1990 and, with increasingly more synthetic oil production and frontier oil production coming on-stream, a net import reduction to zero by 1995.

6.3 THE NATIONAL ENERGY PROGRAM

The National Energy Program, introduced on October 28, 1980, caused the single most significant effective change of the energy industry in Canada in recent years. Its major policy elements are the Canadianization of the energy industry and the diversion of emphasis from mainland oil to the Canada Lands.

As part of the NEP (Government of Canada 1980), the Government of Canada has provided an incentive program that covers maximum 80% of incentive payments to any company of 75% Canadian ownership rate (subsequently reduced to 65%) for qualified exploration expenditures on Canada Lands. Any lower Canadian ownership rating (COR) would result in sharply reduced incentives.

This structure is particularly conducive to the shifting of investments to the development of the offshore acreage held by Canadian companies. During 1981 and early 1982, it has increased the pressure on heavy oil upgraders and oil sands projects to remain competitive as investment options with offshore oil projects.

Most of the attractive offshore acreage had been acquired earlier by the multi-national companies and, subsequent to the introduction of the NEP, many of the Canadian companies sufficiently powerful to make use of these incentives, found insufficient acreage available to utilize the incentives. With the introduction of Bill C-48 however, the Federal Government created the vehicle for redistributing much of this attractive, yet currently unworked acreage to companies of sufficient Canadian ownership rating. During 1981 and early 1982, the effect of this policy has become apparent in that several Canadian companies have acquired rights from multi-national companies via farm-in agreements, or else purchased the multi-nationals' rights entirely. While the actual distribution of unworked acreage has not yet taken place, a list of "interested parties" is being drafted in Ottawa.

7. ANNOUNCED PROJECTS AND PROJECTED EQUIPMENT REQUIREMENTS FOR OFFSHORE AND ARCTIC PROJECTS

7.1 INTRODUCTION

Ongoing activities are shared by few companies in each of the major regions. As a recent development, several of the companies are involved in two or more areas.

With the advent of the NEP and Bill C-48, many Canadian companies have substantially increased their acreage holdings.

Activities and plans for the three major areas, the East Coast, the Beaufort Sea and the Arctic Islands, differ vastly in type and quantity of the hydrocarbon resource, the environmental conditions and the technology for exploration, production and transportation to market.

The two additional areas for potential exploration, the Hudson Bay and the West Coast, play a rather speculative role to date.

NOTE: Only in this section will the production capacity figures forecasted be shown in SI and imperial units (b/d and MMSCFD).

7.2 GRAND BANKS - HIBERNIA AREA

7.2.1 PAST ACTIVITIES

The Hibernia field was discovered by Chevron in August, 1979, producing, when Mobil as the operator of the group tested one well, 3180 m^3/d (20,000 b/d).

In the Avalon Basin and the Jeanne d'Arc Basin, a total of seven wells were tested during 1981 by Mobil, with only one hole being dry (G-55A). The Hibernia K-18 could be the most prolific of all of the appraisal wells.

Current activities or plans for 1982 include appraisal and exploration wells by Mobil, Petro Canada and Shell Canada.

The regulatory dispute between Ottawa and St. John's considerably hampered the anticipated resurgence in drilling activity for the summer of 1982 and could mean that only up to ten rigs will actively work in the Grand Banks area this summer.

7.2.2 PROJECT OUTLOOK

While the Hibernia structure is almost fully delineated, the area further east and in deep water up to 1,000 meters, named the Flemish Pass, will be explored by Imperial Oil in 1983 or 1984. The Company claims that its current problem is finding semi-submersible drill rigs capable of drilling in deep water in addition to the uncertainty created by the offshore dispute between Ottawa and Newfoundland. (Daily Oil Bulletin, March 22, 1982).

For the production of oil from the Hibernia structure, Mobil, by far the most advanced operator in the area, is planning on a floating production system as the most practical. Envisaged is a typical conventional twin-hull semi-submersible vessel of over 130 m in length and 88 m in width, with a draft of about 26 m and an air gap of more than 16 m. This structure would have a deckload of about 15,000 tonnes, using structural steel of about 18,000 tonnes in weight and having a displacement of about 53,000 tonnes. The semi-sub will have an accommodation of 100 people, and be self-propelled and designed to withstand 37 m waves and 51 m/s winds. As the production unit, it will be linked to a storage vessel of a similar configuration, but of considerably larger dimensions - 254 m x 71 m, with a designed load draft of 52 m and a displacement of about 400,000 tonnes. The storage unit will be capable of quick disconnect, and propulsion under its own power, and have the capability of mooring and loading shuttle tankers. (Barroll, A.E., 1981).

To support the above production system, several dedicated shuttle tankers and a shore-based single buoy tanker loading facility would be required. Mobil Oil represents that, because of the proven iceberg occurrence in the Hibernia area, pipeline transportation from the production system to the East Coast shore is not feasible. The shuttle tankers would be approximately 262 m long, 39 m in beam and draw about 13 m loaded. They would be designed in a double-hull construction with segregated ballast and cargo and be powered by an 18,000 h.p. single screw propulsion system.

Additionally, the floating production system would require work boats of some ice-reinforced class of about 79 m in length, 18 m in beam, drawing about 6 m. Their power system would provide about 11,000 h.p. for the 1650 tonnes dead weight vessel.

Further required to support this production system are facilities such as subsea templates and off-loading equipment at the East Coast ports.

If the described production system is designed for a capacity of 32,000 m^3/d (200,000 b/d), four of the systems would be required to fully exploit the Hibernia structure to its currently proven extent.

While Mobil Oil could soon begin final design and engineering, the jurisdictional negotiations need to be settled first. It is foreseen that these negotiations will not be satisfactorily concluded for the operators to make final investment committments before 1983. The first step, installation of the subsea drilling templates, could not be completed before 1985. This will delay field delineation drilling, production/injection well completions and other operational interim producing systems for the proving of production risers until about 1987. Following this, the installation of the floating production systems will likely occur on a staged basis beginning in 1987 with the production of the first 32,000 m^3/d (200,000 b/d), followed with an additional production system every other year. (A.E. Barroll, 1981).

It is assumed here that additional commercial discoveries on the Grand Banks will be made throughout the 1980's. The production systems to be used following the first generation floating systems could well be fixed platforms for operation in the 1980's with the first production of perhaps 32,000 m^3/d (200,000 b/d) by 1987.

It is significant that B.P. Canada has already cancelled its plan to return to East Coast drilling operations. Shell has delayed its six-well program until later this year. It is most likely that the exploration activities in Hibernia will strongly increase by the time jurisdictional disputes over offshore rights are settled, and industry is provided with the confidence of a well defined and satisfactory taxation basis.

Exploration for oil and natural gas off the East Coast will likely see a varied scenario in the short term:

- currently, Hibernia is rather cautiously approached;
- Scotia Shelf, while to date only gas has been proven, activity is heating up which could accelerate if the Banquereau structure shows good oil potential;
- in Labrador, low paced exploration work will continue well into the 1990's;
- if, by 1984, the Federal and Newfoundland governments have settled their dispute, exploration will likely experience a very strong boost, particularly in the deeper waters east of Hibernia.

It is therefore expected that given the currently available heavy drilling rigs, newly built equipment will be needed to satisfy the increasing demand.

Semi-submersible drilling rigs of a high deck load capability of around 3,500 to 4,000 tonnes of the Aker H.3.2, Zapata SS-4000, or Gotaverken Arendal GVA-4000 type will likely be used for adaptation to the specific outfitting requirements of the various East Coast areas.

It is expected that no new jack-up rigs will be ordered for Canada, for there will be plenty available from the international market and the semi-submersibles are more universally applicable in Canadian waters. These semi-submersible rigs will be ice-reinforced in the hulls, legs and underdeck areas. Support vessels for all functions will be required at about one per new rig.

The demand for exploration rigs will be greatest during the latter part of this decade.

Table 7-1 lists the forecast for drilling rigs and supply boats for exploration purposes.

The timing of producing oil from the Hibernia structure is dependent on the settlement of the current jurisdictional dispute. For industry to invest in the field, oil price, taxation and stability of energy policies will have to be at satisfactory levels.

It is anticipated that a combination of favourable terms will emerge in 1984. 1985 could therefore be the first year of systems construction activity.

Table 7-2 lists the equipment for oil production. A staged start-up of the first field is expected, producing fully 32,000 m^3/d (200,000 b/d) by 1988. Three years later, the second system could follow, with number three in operation by 1994 at increased capacity.

For the production systems following in the 1990's, the concept could change to concrete gravity structures with protective subsea berm and integrated storage capacity. Such a system could well produce 80,000m^3/d (500,000 b/d) when fully expanded.

TABLE 7-1

PROJECT: EAST COAST GAS & OIL EXPLORATION

OPERATOR: MOBIL, PETRO CANADA, SHELL, GULF, OTHERS

REFERENCE PROJECT DESCRIPTION: 7.2.2

		EQUIPMENT REQUIREMENTS		
CAPACITY (B/D) (Incremental)	TIMING (Year)	TYPE	QUANTITY	SIZE
	1984	DRILLING SEMI	1	Class 4000
	1985	SUPPLY BOAT	1	240'
	1986	DRILL RIG SEMI	2	Class 4000
		SUPPLY BOATS	2	240'
	1988	DRILL RIG SEMI	1	Class 4000
		SUPPLY BOAT	1	240'
	1991	DRILL RIG	1	Class 4000
		SUPPLY BOAT	1	240'

While subsea templates and production risers are not considered significant for the 25 mm thick steel plate market, the timing for both of the first systems is identified.

Table 7-3 lists the additional equipment required to produce the gas associated with the oil production after gas re-injection cannot further be continued.

TABLE 7-2

PROJECT: GRAND BANKS, HIBERNIA-OIL PRODUCTION
OPERATOR: MOBIL, PETRO CANADA
REFERENCE PROJECT DESCRIPTION: 7.2.2

CAPACITY (B/D) (Incremental)	TIMING (Year)	EQUIPMENT REQUIREMENTS TYPE	QUANTITY	SIZE
	1985	SUBSEA TEMPLATE*	1	
	1986	PRODUCT RISER*	1	
		SUPPLY BOATS	2	240'
50,000	1987	PRODUCTION SEMI	1	400'x270'
		STORAGE SEMI	1	400,000 T
		TANKER	1	150,000 T
		SBM	1	
		SUPPLY BOATS	2	240'
150,000	1988	TANKER	1	150,000 T
250,000	1991	PRODUCTION SEMI	1	400'x270'
		STORAGE SEMI	1	400,000 T
		TANKERS	2	150,000 T
		SBM	1	
		SUPPLY BOATS	2	240'
300,000	1994	PRODUCTION SEMI	1	400'x270'
		STORAGE SEMI	1	400,000 T
		TANKERS	2	200,000 T
		SBM	1	
		SUPPLY BOATS	2	240'
200,000 (EXPANSION TO 500,000 LATER)	1999	PRODUCTION CONCRETE GRAVITY PLATFORM INCLUDING STORAGE	1	800' 500,000 T
		TANKERS	2	200,000 T
		SUPPLY BOATS	2	240'

* NOT FURTHER CONSIDERED

TABLE 7-3

PROJECT: GAS PRODUCTION HIBERNIA (ASSOCIATED WITH OIL PRODUCTION)

OPERATOR:

REFERENCE PROJECT DESCRIPTION: 7.2.2

		EQUIPMENT REQUIREMENTS		
CAPACITY (Incremental)	TIMING (Year)	TYPE	QUANTITY	SIZE
	1995	ACCOMMODATION SEMI	1	Class 4000
	ASSOCIATED GAS PRODUCTION (AFTER RE-INJECT.) ASSUME 1995 GAS PROCESSING ON SITE TO LNG, OR METHANOL OR OTHER.			
	1995	PROCESSING SEMI	1	Class 4000
		STORAGE SEMI	1	Class 10,000
		LNG/METHANOL CARRIER	1	125,000 m^3
		SUPPLY BOATS	2	240'

7.3 SCOTIA SHELF

7.3.1 PAST AND CURRENT ACTIVITIES

For 1982, it is expected that about $250 million will be spent in exploration programs, including further delineation of the Sable Island natural gas structure, the Banquereau oil structure and several new wells by several of the newcomers in the area.

Mobil Oil will use its jack-up Zapata Scotian to further delineate the Venture B-13 well which is located about 3 km northeast of the original Venture D-23 discovery well, drilled in 1979. The jack-up Rowan Juneau is drilling the well Venture B-43.

Shell Canada is planning on a six well program to be drilled for itself and the newly formed group Onaping/Scotia. The Company plans to use its Sedco 709 semi-submersible drill rig. To develop its large holdings off Nova Scotia, Shell has farmed out a 25% interest to Norcen Energy Resources Ltd. and to CDC Oil & Gas in exchange for the funding of a $100 million drilling program.

Two of the newcomers to the Scotian Shelf are Hudson's Bay Oil & Gas and Inco Energy Resources Ltd. HBOG will primarily fund a $1 million seismic program.

The Petro Canada operated and partially owned Banquereau group includes Husky Oil, L.K. Oil & Gas, Lochiel Exploration, Petro Ventures Resources, Polaris Petroleums, Ranger, Roxy Petroleum and Universal Explorations. This group plans to spend $50 million in 1982 to delineate the Banquereau structure. Petro Canada's fleet of drilling rigs should include, by 1983, the currently active semi-sub Bowdrill I, owned by Bow Valley Offshore Drilling Ltd., and the SDS Vinland, a semi-sub currently being fabricated at a Swedish shipyard. The Sedco 710 is scheduled for arrival in 1983.

To support its drilling activities, Petro Canada has ordered the construction of supply boats (UT-704, with Marystown Shipyards) and an ice-reinforced seismic boat to be built by Marine Industries and delivered in 1983.

The activity on the Scotian Shelf will be hottest among all potential hydrocarbon areas.

The significant natural gas discoveries in the Sable Island area are in relatively shallow water of about 65 m depth. Mobil Oil believes that conventional steel production platforms can be used for drilling and subsequent conversion to production. Such a structure would consist of piling, templates and deck section. The tubular members would comprise about 3,000 tonnes, a portion of which would be made from heavy plate, and the deck section would consist of about 1,000 tonnes of tubular and structural steel.

7.3.2 PROJECT OUTLOOK

The Sable Island reserves are large enough for commercial exploitation. The availability of anticipated low cost transportation to the Maritime Provinces through the T, Q and M pipeline system would impose strong economic pressure on a Sable Island production system. In addition, the oil production at Hibernia will likely generate a large amount of associated gas, which at some time will have to be produced and brought to shore because of the inability of the reservoirs to absorb re-injected gas. Therefore, the market demand for natural gas will require export to the U.S., to warrant the investment risk of Sable Island development.

It is expected that the development will take this course: Increased exploration during 1982 and 1983. Production development will begin and soon be followed by the first gas deliveries of up to 15 x $10^6 m^3$/d (500 MMSCFD) by 1987.

For the crude oil prospects in the area, continuing exploration is expected, providing the Banquereau structure shows promise. While this might result in some production of oil in the 1990's, none is actually forecast.

The first steel jacket platform will be installed in early 1987, requiring two new supply boats. Typical current technology will be used with no ice-reinforcing or other protection.

Four years later, another production system would be put into place.

Increased production would be achieved with the third system of 21 x 10^6 m^3/d (750 MMSCFD) by 1997. The systems build-up is shown in Table 7-4.

TABLE 7-4

PROJECT: SABLE ISLAND - NATURAL GAS PRODUCTION
OPERATOR: MOBIL OIL, PETRO CANADA
REFERENCE PROJECT DESCRIPTION: 7.3.2

		EQUIPMENT REQUIREMENTS		
CAPACITY (Incremental)	TIMING (Year)	TYPE	QUANTITY	SIZE
500 MMCFD	1987	STEEL JACKET PLATFORM	1	250' 8 PILES
		SUPPLY BOATS	2	200'
500 MMCFD	1990	STEEL JACKET PLATFORM	1	250' 8 PILES
		SUPPLY BOATS	2	200'
750 MMCFD	1997	STEEL JACKET PLATFORM	1	350' 12 PILES
		SUPPLY BOATS	2	200'

7.4 LABRADOR SHELF

7.4.1 PAST ACTIVITIES

Beginning with the Leif L-38 well drilled in 1971, a long list of experiences specific to area and environment was started.

All of the 26 wells drilled by 1981 in the area are on the Labrador Shelf (except two).

High iceberg frequency, strong south currents and a drilling season of only 100 days per year result in considerably slower exploration drilling than in other areas.

During the 1980 and 1981 seasons, respectively, five and three dynamically positioned drillships were used. The area has yet to be delineated and proven commercial.

7.4.2 PROJECT OUTLOOK

The 1982 program should be similar to 1981 in level of effort. Even if drilling results in 1982 should be good, much more exploration and delineation will be required. With the area representing the strongest challenge of all the East Coast exploration acreages, production of oil or gas will likely occur not before late in the second forecast decade. Therefore, the contribution to thick steel plate demand by the Labrador area is considered negligible.

7.5 BEAUFORT SEA

7.5.1 PAST AND CURRENT ACTIVITIES

Active searching for petroleum in the Beaufort Sea and the MacKenzie Delta began in the early 1960's with Imperial Oil drilling the first hole, Immerk, in 1972. 18 manmade islands have since been built in the shallow waters of the MacKenzie Delta. Drilling in deeper Continental Shelf waters of the Beaufort Sea began with use of Dome's Canmar fleet in 1976. These ships, Canmar Explorer I, II and III had drilled 12 wells by the end of 1980.

The major players in the Beaufort are Dome Petroleum Limited, Esso Resources Canada Limited and Gulf Canada Resources, Inc.

Esso is now taking care of Imperial Oil's exploration and production interests in the Beaufort. It has, jointly with its parent, spent up to $500 million in exploration and drilling of 73 wells. It has proven gas reserves of more than 85×10^6 m^3, (3 TCF) at Taglu on Richards Island. Its well Issungnak resulted in an oil discovery when drilled for $33 million in 1979. Esso has pioneered the exploration from artificial sand dredged islands.

Dome Petroleum has invested more than $400 million in its ice reinforced drilling and support fleet and in base facilities. This includes four ice-reinforced drillships, eight supply vessels, three barges, a cargo carrier and the Class 4 Icebreaker Kigoriak. To date, the Company has found oil in the discoveries at Nektoralik, Kopanoar, Koakoak and Tarsiut in addition to gas discoveries at Ukalerk, Tingmiark and Nektoralik.

Like Esso, Dome has been very active since the 1970's in the attempt to develop exploration technology using both artificial islands and drillships and in development of production technology (to date theoretical) and transportation technology based on ships. With its Canadian built research icebreaker Kigoriak, the Company had demonstrated a novel approach for development of ice-going vessels. Dome has currently detailed plans for very large oil tankers, icebreakers of various sizes and capabilities, supply and work boats as well as Arctic construction equipment.

Gulf Canada Resources Inc. has extensive land holdings in the Beaufort Sea, MacKenzie Delta, the Arctic Islands and the East Coast. In the late 1960's and early 1970's, Gulf drilled in the MacKenzie Delta over 40 on-shore wells, which resulted primarily in the major gas finds at Parsons Lake.

Since 1976, Gulf participated in the Kopanoar and Tarsiut oil discoveries and the Ukalerk gas discovery. Jointly with Esso, it participated in the Isserk gas discovery and the Isumiak oil discovery, both drilled from artificial islands. Currently, Gulf has under construction a steel caisson and a conical drilling unit for exploration for oil.

7.5.2 OUTLOOK

7.5.2.1 INTRODUCTION

In the past, many speculative suggestions on type, pace, dollar requirements and oil production levels and means for Beaufort Sea oil development were made by interested groups.

In order to arrive at a believable thick steel plate demand forecast for the Beaufort Sea, only the most recent public statements were considered - those presented to the Special Committee to the Senate for Northern Resources Transportation in Ottawa, March, 1982. Support for detail was acquired from the developers.

While the group of companies active in the Beaufort, including Gulf, Esso and Dome, identified in the document - Dome et al, June, 1981 - that it's proposed oil production development pace is considered the maximum limit of technical achievability, all three companies develop their own exploration and production plans for the area independently.

7.5.2.2 GULF CANADA RESOURCES, INC.

Gulf is currently studying several types of artificial islands for exploration and production facilities in the Beaufort. The Company has currently under construction in a Japanese shipyard, a $200 million steel caisson and one $140 million conical drilling unit, both to be supported by two Class 4 ice-breakers and two

Class 4 supply ships, all currently being constructed. Gulf feels that the caisson retained island is economically suitable for production in water depths to 25 m, while Dome's APLA system could be used in deeper water. The icebreaker is 88 m long and has an 18,600 h.p. power plant, while the supply ships measure 95 m and are supplied with 14,000 h.p.

Gulf sees the development of the Beaufort producing oil from two fields totalling 48,000 m^3/d (300,000 b/d) by the mid-1990's. This level of production will result from a phased introduction of smaller production fields which will allow the testing of novel production techniques as well as a gradual build-up of the transportation system. While the Company sees, eventually, an oil pipeline being used for transporting the resource to southern markets, a small, but increasing fleet of tankers to ship crude to market would enhance the possibility of earlier production. It is significant in Gulf's view that this phased approach beginning with small-scale production, provides earlier cash flow to attract investor funds for further development projects.

7.5.2.3 ESSO RESOURCES CANADA LIMITED

Esso has currently under construction its steel caisson system at a shipyard in Japan. The reuseable artificial island system is a significant deviation from Esso's practice, namely, the dredged sand island. It allows the Company to concentrate more on the Western Beaufort where sand for dredging is not as abundantly available as in the Eastern section. The system is estimated to cost about $50 million. It will require an additional $1 million worth of scientific instruments, plus a possible $80 million worth of support vessels. The latter, however, Esso is planning to acquire on a lease program basis.

Esso tends more strongly towards the pipeline transportation system than do both Gulf and Dome. The Company's Issungnak Island has been the most promising to date. Esso shares its 50% interest in the acreage with Gulf at 28.85%, Aquitaine Company of Canada 15.15%, Norcen Energy Resources 4% and Westmin Resources 2%. This island is a strong prospect for future commercial production and the Company, with recently drilled wells on the Alerk artificial island and with tests possible at West Atkinson, considers its future in the Beaufort to be very favourable.

In its brief to the Senate Committee studying Northern Resources Transportation Systems in March, 1982, Esso supported its belief that the Beaufort potential is very favourable and will be a major source of petroleum supply to Canada during the 1990's. The Company recommends a gradual build-up of production capacity, beginning with about 4,000 m^3/d (25,000 b/d) by 1988, growing to about 64,000 m^3/d (400,000 b/d) by the year 2000.

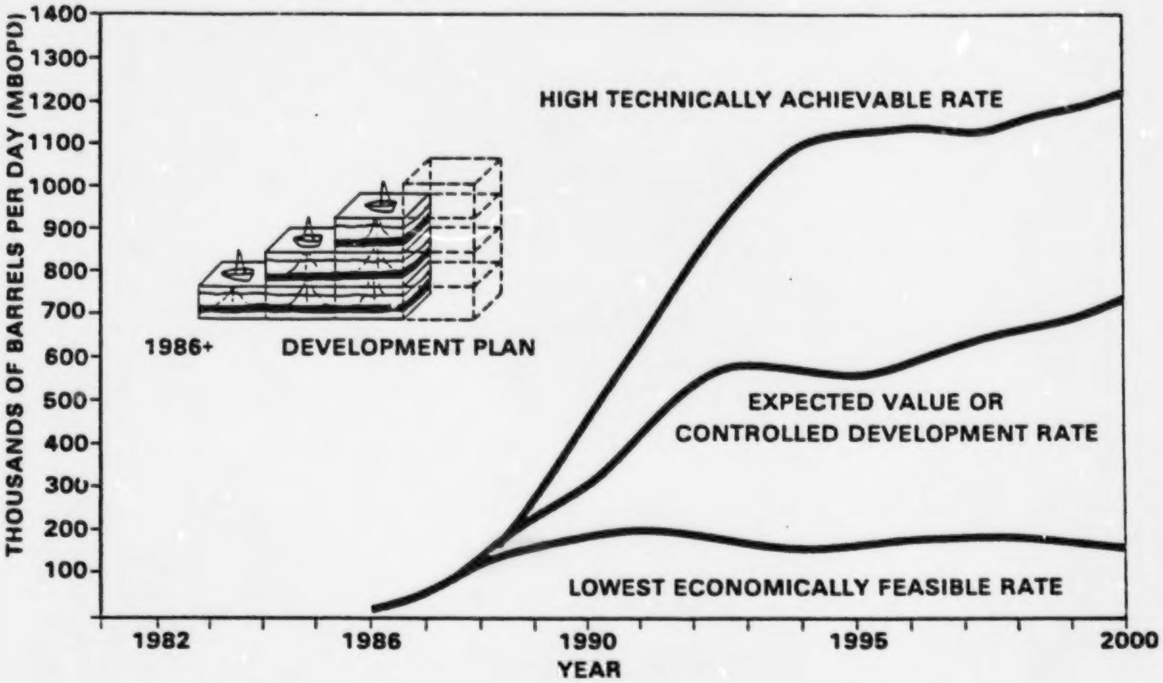
7.5.2.4 DOME PETROLEUM LIMITED

In its submission to the Special Committee of the Senate on the Northern Pipeline, Dome suggested that with a projected oil supply shortfall of 56,000 m^3/d (350,000 b/d) by 1990, rising to 96,000 m^3/d (600,000 b/d) by the year 2000, an all out effort should be made to delineate, prove and gear-up for production of the Beaufort Sea resources. (Dome Petroleum, 1982).

Based on the highest technically achievable development and the lowest economically feasible production, Dome has forecasted that by the year 1990, production should be between 32,000 m^3/d (200,000 b/d) and 72,000 m^3/d (450,000 b/d) of oil; the expected value being 48,000 m^3/d (300,000 b/d). By the year 1995, the respective values are 32,000 m^3/d (200,000 b/d) and 175,000 m^3/d (1.1 million b/d) with an expected value of 38,000 m^3/d (550,000 b/d). Its forecast figures for the year 2000 are 32,000, 191,000 and 128,000 m^3/d, respectively, (200,000, 1.2 million and 800,000 b/d), see Figure 7-1.

FIGURE 7-1

DOME'S PRODUCTION FORECAST TO THE YEAR 2000



Source: Dome (1982)

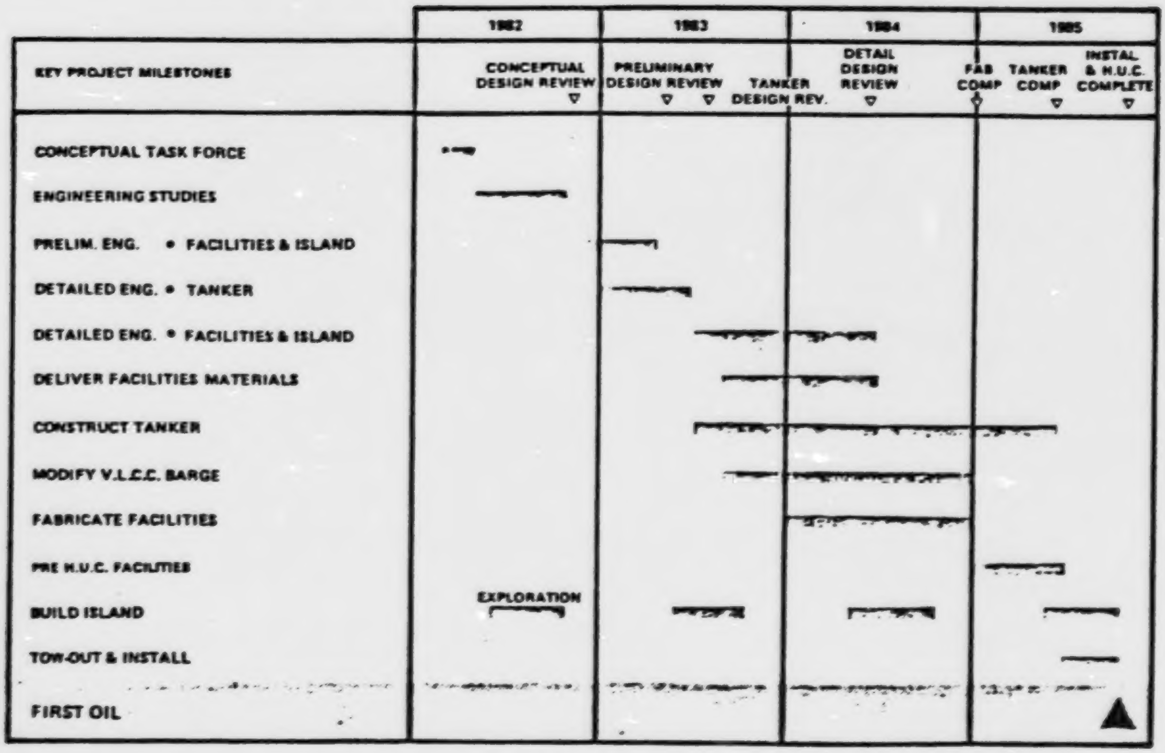
To achieve this ambitious production schedule, Dome's current development plan for the south Beaufort Sea is based mainly on the three oil discoveries - Tarsiut, Koakoak and Kopanoar.

Over the period between 1982 and 1990, the Tarsiut field would be delineated and developed with production to start in late 1985. To exploit the full potential of Tarsiut, five islands are anticipated. The Koakoak reservoir is planned for three islands with delineation to begin in late 1983, development during 1984 and production not earlier than 1986.

Currently, for the Kopanoar field, Dome plans two islands and expects that delineation will require about three and one half years. Production systems are planned to use sand dredged artificial islands with a retaining wall system called the Arctic Production Loading Atoll (APLA).

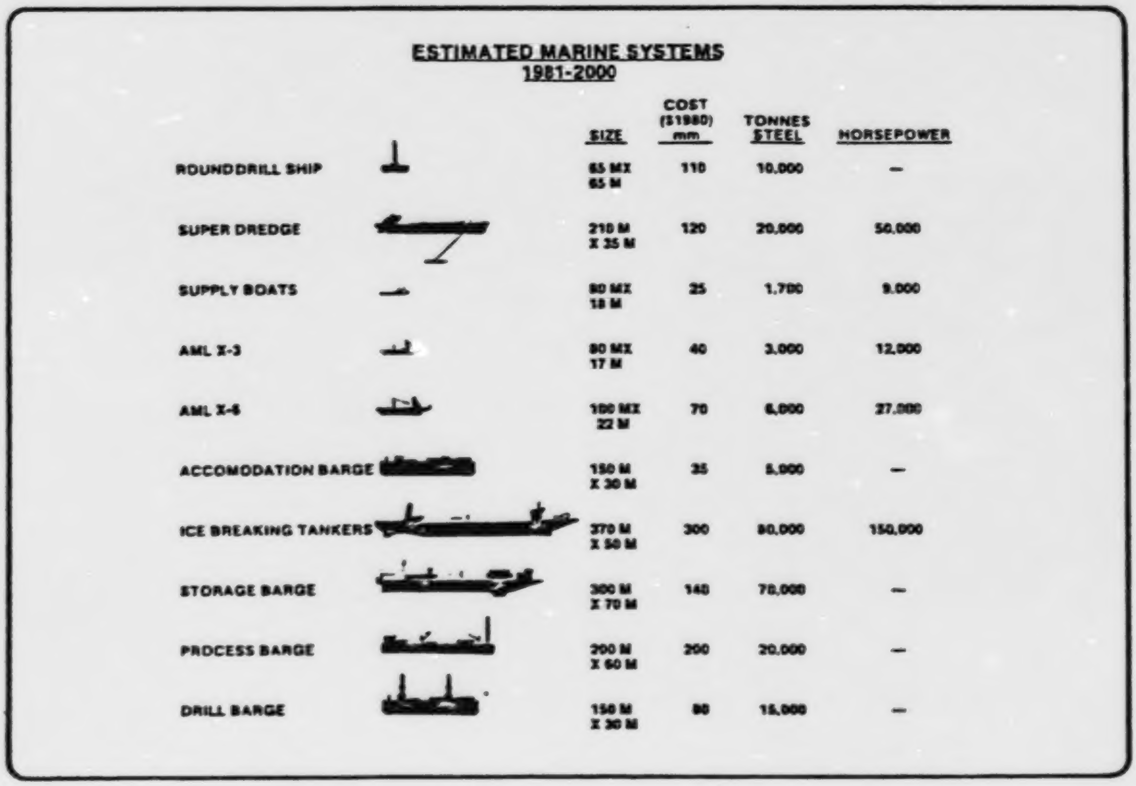
Dome's schedule for the technically feasible case - first oil production by the end of 1985 - is shown in Figure 7-2.

FIGURE 7-2
DOME'S SCHEDULE FOR FIRST OIL-
-PRODUCTION BY THE END OF 1985



The requirements to support this development schedule are identified in the following tables: Table 7-5 identifies by size, cost, tonnage of steel and horsepower where applicable, the range of vessels required by Dome. Table 7-6 correlates the hardware and the calendar of the development plan to the year 1995.

TABLE 7-5



ESTIMATED MARINE SYSTEMS
1981-2000

	SIZE	COST ($1980) mm	TONNES STEEL	HORSEPOWER
ROUNDDRILL SHIP	65 M X 65 M	110	10,000	—
SUPER DREDGE	210 M X 35 M	120	20,000	50,000
SUPPLY BOATS	80 M X 18 M	25	1,700	9,000
AML X-3	80 M X 17 M	40	3,000	12,000
AML X-6	100 M X 22 M	70	6,000	27,000
ACCOMODATION BARGE	150 M X 30 M	35	5,000	—
ICE BREAKING TANKERS	370 M X 50 M	300	80,000	150,000
STORAGE BARGE	300 M X 70 M	140	70,000	—
PROCESS BARGE	200 M X 60 M	200	20,000	—
DRILL BARGE	150 M X 30 M	80	15,000	—

Dome has been planning the establishment of a world class shipbuilding capacity. With the purchase of Davy Shipbuilding Ltd., in Quebec, the first step in an ambitious program was achieved.

TABLE 7-6

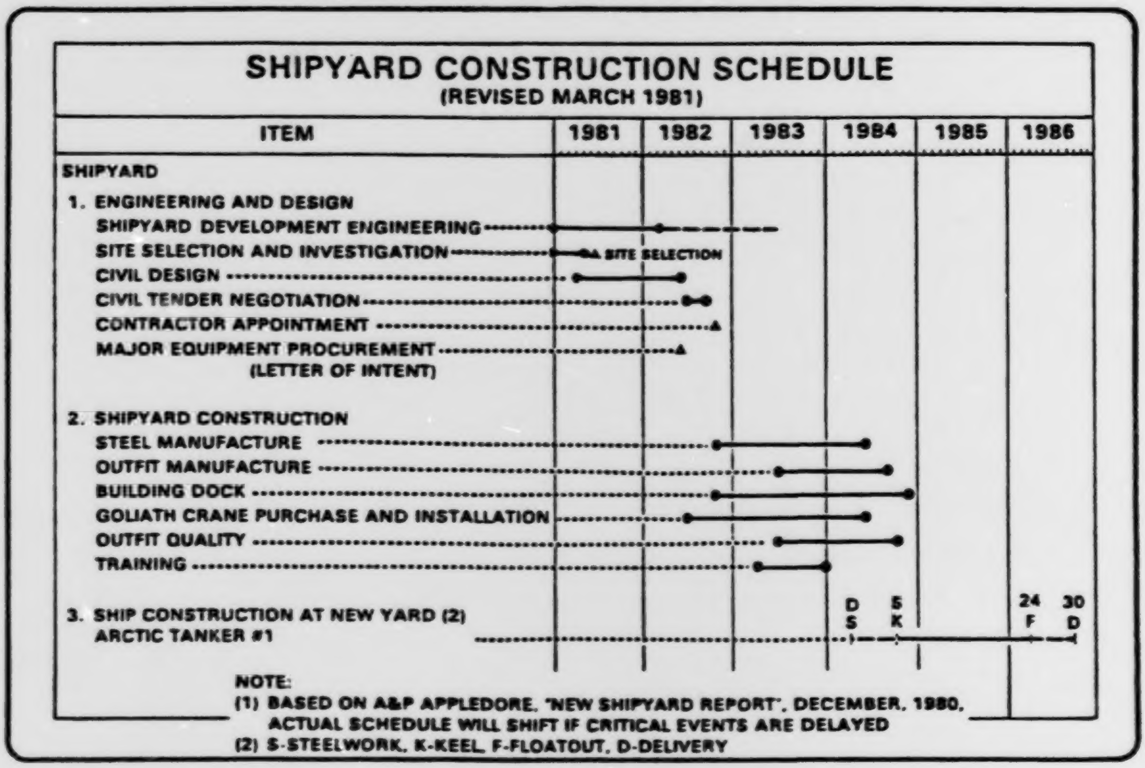
HARDWARE & CALENDAR OF DEVELOPMENT PLAN TO THE YEAR 1995

VESSEL TYPE	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
SMALL VESSELS															
AML-3 (12)	—	—	—	—▲	▲▲▲		▲▲			▲▲	▲	▲	▲	▲	
AML-6 (4)	—	—▲			▲			▲			▲				
SUPPLY BOAT (22)	—	—	—	—▲▲	▲▲	▲▲		▲▲	▲▲	▲▲	▲▲	▲▲	▲▲	▲▲	▲▲
ACCOMMODATION BARGE															
CONSTRUCTION (3)	—	—	—▲	▲					▲						
OPERATIONS (5)	—	—	—	—	—▲		▲			▲		▲		▲	
MEDIUM VESSELS															
DRILLING BARGE (17)	—	—	—	—▲	▲	▲▲▲▲		▲▲	▲▲	▲▲	▲	▲	▲	▲	▲
ROUND DRILLSHIP (5)	—	—▲			▲			▲	▲		▲				
DREDGE (6)	—	—	—▲	▲▲▲						▲		▲			
LARGE VESSELS															
PROCESS BARGE (5)	—	—	—	—	—▲		▲			▲		▲		▲	
STORAGE BARGE (5)	—	—	—	—	—▲		▲			▲		▲		▲	
ARCTIC CRUDE CARRIERS (25)	—	—	—	—	—▲	▲	▲▲▲	▲	▲	▲▲▲▲▲	▲▲▲	▲▲▲	▲▲▲	▲▲▲	▲▲

The shipyard construction schedule is shown in Table 7-7.

Dome requested from the Federal Government, during its presentation to the Senate in March, 1982, an early approval in principal for the Beaufort Sea development. The Company indicated that such an approval was necessary to meet the development schedule for first oil production in 1985.

TABLE 7-7



NOTE:
(1) BASED ON A&P APPLEDORE, "NEW SHIPYARD REPORT", DECEMBER, 1980, ACTUAL SCHEDULE WILL SHIFT IF CRITICAL EVENTS ARE DELAYED
(2) S-STEELWORK, K-KEEL, F-FLOATOUT, D-DELIVERY

Exploration and production activities in the Beaufort Sea will be interwoven according to Dome's plans.

Current timing to achieve an early start is already against Dome's goal:

- the environmental impact statement has not been submitted to the Federal Government, hence an approval will not be available in 1982;
- public hearings have timetables in terms of years, particularly if native rights and environmental sensitivities are involved;
- the shipyard schedule is outdated.

If the Company receives the green light by Cabinet in 1983/84, it will be an ambitious undertaking to produce oil commercially in any quantity by 1988.

Incremental production increase will likely occur at 8000 m^3/d (50,000 b/d) per two year intervals.

It is forecast that the pace of development will be less ambitious and reach about 64,000 m^3/d (400,000 b/d) by the year 2000. (See Table 7-8).

This schedule, of course, substantially reduces the equipment requirements.

With the first tanker required by 1987, the second by 1988 and the third by 1989, their construction in Dome's planned own world class shipyards is doubtful given Dome's schedule of March, 1981 (Table 7-7). Therefore, of the total of ten tankers needed by the year 2000, at best, seven or eight could be produced in Canada.

In addition to Dome's production and equipment requirements will be those of Esso and Gulf.

Steel requirements for building of exploration islands will be similar to Gulf's or Esso's for Dome will likely want to test a steel construction for comparison with the concrete version of Tarsiut.

The APLA's will likely require only steel of thicknesses not exceeding 19 mm (3/4").

TABLE 7-8

PROJECT: BEAUFORT SEA - OIL EXPLORATION AND PRODUCTION

OPERATOR: DOME

REFERENCE PROJECT DESCRIPTION: 7.5.2.4

CAPACITY (Incremental)	TIMING (Year)	EQUIPMENT REQUIREMENTS TYPE	QUANTITY	SIZE
B/D				
	1984	DREDGE	1	
		CONSTRUCTION BARGE	1	
		AML 6	1	100mx22m
		SUPPLY BOAT	1	
	1985	AML 4	1	
		DRILLING BARGE	1	
		SUPPLY BOAT	1	
	1986	AML 4	1	
		SUPPLY BOAT	1	
		DREDGE	1	
25,000-50,000	1987	TANKER	1	200,000 T
	1988	TANKER	1	
		PROCESS BARGE	1	
		STORAGE BARGE	1	
		AML 6	1	
		AML 4	1	
		SUPPLY BOAT	1	
		OPERATIONS BARGE	1	
		DREDGE	1	
50,000	1989	TANKER	1	
		DRILLING BARGE	1	
		ROUND DRILLSHIP	1	
		CONSTRUCTION BARGE	1	

Cont/....

TABLE 7-8 (Continued)

PROJECT: BEAUFORT SEA - OIL EXPLORATION AND PRODUCTION

OPERATOR: DOME

REFERENCE PROJECT DESCRIPTION: 7.5.2.4

CAPACITY (B/D) (Incremental)	TIMING (Year)	EQUIPMENT REQUIREMENTS TYPE	QUANTITY	SIZE
Cont/....				
50,000	1990	TANKER	1	
		STORAGE BARGE	1	
		PROCESS BARGE	1	
		DRILLING BARGE	1	
		AML 4	1	
		SUPPLY BOAT	1	
	1991	TANKER	1	
		STEEL CAISSON	1	
		DRILLING BARGE	1	
		ROUND DRILLSHIP	1	
		SUPPLY BOAT	1	
		OPERATIONS BARGE	1	
		DREDGE	1	
50,000	1992	TANKER	1	
		AML 4	1	
		SUPPLY BOAT	1	
	1993	ROUND DRILLSHIP	1	
		SUPPLY BOAT	1	
50,000	1994	TANKER	1	
		AML 4	1	
		SUPPLY BOAT	1	
50,000	1995	TANKER	1	
		OPERATIONS BARGE	1	

Cont/....

TABLE 7-8 (Continued)

PROJECT: BEAUFORT SEA - OIL EXPLORATION AND PRODUCTION

OPERATOR: DOME

REFERENCE PROJECT DESCRIPTION: 7.5.2.4

CAPACITY (B/D) (Incremental)	TIMING (Year)	EQUIPMENT REQUIREMENTS TYPE	QUANTITY	SIZE
Cont/....				
	1996	SUPPLY BOAT	1	
		STEEL CAISSON	1	
50,000	1997	TANKER	1	
		PROCESS BARGE	1	
		STORAGE BARGE	1	
	1998	AML 4	1	
		SUPPLY BOAT	1	
	1999	DRILLING BARGE	1	
		AML 4	1	
50,000	2000	TANKER	1	
		SUPPLY BOAT	1	

SUMMARY OF EQUIPMENT

TANKERS	10
DREDGES	4
PROCESS BARGES	3
STORAGE BARGES	3
DRILLING BARGES	5
ROUND DRILLSHIPS	3
CONSTRUCTION BARGES	2
OPERATIONS BARGES	3
AML 4	7
AML 6	2
SUPPLY BOATS	12
STEEL CAISSONS	2

7.5.2.5 ESSO/GULF

Esso has a good potential for commercial oil production from its Issungnak field. With further exploration from sand islands and with its caisson drill systems, possibly operationally proven by 1984, the Company could acquire a second caisson system by 1986/87.

Similar prospects exist for Gulf. It is estimated that only one of these will continue to be active in the Beaufort, while the other represents its interests.

Given some success during exploration, the Company could well begin production of 4000 m^3/d (25,000 b/d) by 1988. Following with a progressive development of new capacity every other year, total production could reach 24,000 to 32,000 m^3/d (150,000 to 200,000 b/d) by the year 2000.

For the purpose of forecasting the equipment requirements, it is assumed that the Company continues its current practice and uses contracted construction equipment. The forecast requirements for Esso/Gulf development are listed in Table 7-9.

TABLE 7-9

PROJECT: BEAUFORT SEA - OIL EXPLORATION AND PRODUCTION

OPERATOR: ESSO/GULF

REFERENCE PROJECT DESCRIPTION: 7.5.2.5

CAPACITY B/D (Incremental)	TIMING (Year)	EQUIPMENT REQUIREMENTS TYPE	QUANTITY	SIZE
	1985	SUPPLY BOATS	2	
	1986	STEEL CAISSON	1	
		AML 6	1	
25,000	1988	SUPPLY BOATS	2	
		TANKER	1	
		STORAGE BARGE	1	
		PROCESS BARGE	1	
		OPERATIONS BARGE	1	
		AML 4	1	
25,000	1990	ROUND DRILLSHIP	1	
25,000	1992	TANKER	1	
		STORAGE BARGE	1	
		SUPPLY BOAT	1	
25,000	1994	OPERATIONS BARGE	1	
25,000	1996	TANKER	1	
		PROCESS BARGE	1	
		AML 4	1	
25,000	1998	STORAGE BARGE	1	
		SUPPLY BOATS	2	
25,000	2000	TANKER	1	
		PROCESS BARGE	1	

EQUIPMENT SUMMARY

TANKERS	4
PROCESS BARGES	3
STORAGE BARGES	3
OPERATIONS BARGES	2
STEEL CAISSON	1
ROUND DRILLSHIP	1
AML 6	1
AML 4	2
SUPPLY BOATS	7

7.6 ARCTIC ISLANDS

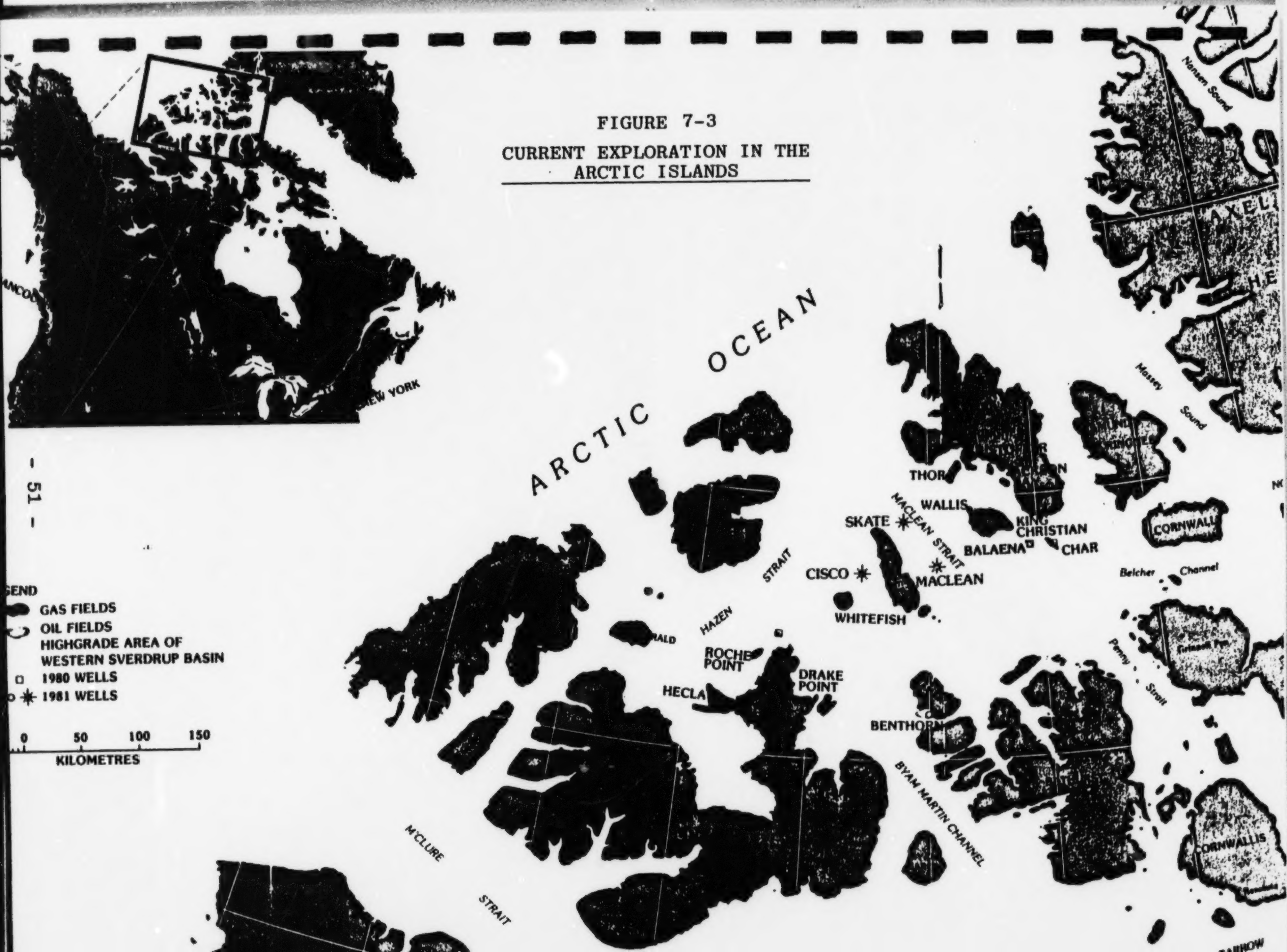
7.6.1 PAST AND CURRENT ACTIVITIES

Two major separate projects are developing in the Arctic Islands. Pan Arctic Oils Limited explores for oil and gas in the area between Melville Island to the southwest and Ellef Ringnes Island to the northeast, see Figure 7-3.

The other project is the Arctic Pilot Project (APP), with its main objective of liquefying the gas found by Pan Arctic and transporting it via LNG carrier through the Northwest Passage to East Coast ports. The project

FIGURE 7-3

CURRENT EXPLORATION IN THE ARCTIC ISLANDS


ARCTIC OCEAN
NEW YORK
Nansen Sound
AXEL
HE
Massey Sound
CORNWALL
Belcher Channel
Penny Strait
CORNWALLIS
THOR
WALLIS
KING CHRISTIAN
BALAENA
CHAR
SKATE
MACLEAN STRAIT
MACLEAN
CISCO
WHITEFISH
STRAIT
HAZEN
ROCHE POINT
DRAKE POINT
HECLA
BENTHORN
BYAM MARTIN CHANNEL
M'CLURE STRAIT
GEND
GAS FIELDS
OIL FIELDS
HIGHGRADE AREA OF WESTERN SVERDRUP BASIN
1980 WELLS
1981 WELLS
0 50 100 150
KILOMETRES

enjoys a very high profile, although it competes with the Polar Gas Pipeline project, which has been in the planning and evaluation stage since the early 1970's.

Although Pan Arctic Oil has discovered oil in four wells - Cisco B-66, Skate B-80, MacLean I-72 and Cisco C-42, natural gas is of greater interest to date, for it is available in commercial quantities.

While awaiting the establishment of a transportation system for its natural gas, Pan Arctic continues to actively explore the Arctic Islands area using shallow water technology adapted from that used in less cold climatic areas.

The current and future use of steel plate of 25 mm and thicker is minimal to the extent that a negligible amount of tonnage is being used in the construction of drill rigs, sub-sea equipment and associated equipment.

The Arctic Pilot Project is designed to test the feasibility of producing natural gas from wells in the Arctic Islands, transporting it via pipeline to the liquefaction plants and shipping the liquefied natural gas by ice-breaking tanker to re-gasification plants on the East Coast. The project sponsors - Petro Canada (also the Project Manager), Nova, an Alberta Corporation, Dome Petroleum and Melville Shipping - plan to prove that this means of transportation is possible on a year-round basis. The project is titled "Pilot" for its small scale (one tenth of what would be considered a full-scale commercial plant project).

A total of eight natural gas producing wells connected via a gathering system and gas processing facilities will produce 50 billion cubic meters of gas for the twenty-year lifetime of the project. From the Drake Point field, the gas will be carried by a 559 mm diameter buried pipeline over 160 km to the south to the Brideport Inlet liquefaction plant. There, the gas will be liquefied and stored in an LNG plant and storage tanks which all will be barge mounted for transportation from the southern manufacturing plants to the Brideport facility. The barges will be berm mounted for the liquefaction plant.

To carry the liquefied natural gas to southern markets, two sophisticated and powerful newly designed LNG carriers with ice-breaking capability will be built. Each vessel will be 375 meters long, with a beam of 42 meters and a draft of 11.5 meters in open water, or 13 meters in ice. Each vessel will have a propulsion system of about 174,000 h.p., which could be fueled by the boil-off vapour of the LNG cargo. The ships will be designed to Arctic Class 7 Ice-Breaker specifications, and each will have a capacity of 140,000 cubic meters. In 1980 dollars, both LNG carriers will cost $530 million; or, $758 million as built. This relates to about 10,000 man-years of effort for both ships.

The project sponsors have planned to have the project started up during mid-1985, but have in the meantime, been delayed by regulatory hearings. While these hearings are already demonstrating substantial opposition to the project, particularly by communities located along the transportation route, it is felt that the project will eventually be approved for its political significance, even despite its lack of economic viability for years to come.

The project start-up date can now be estimated not earlier than 1987, with the procurement of the LNG tankers in 1985.

The process facility barge and the barges for LNG storage will likely be contracted in 1985 as well.

As this Arctic Pilot Project is based on the marketing of natural gas which will have to command a higher price than natural gas available from southern sources, the project is seen not to expand during the forecasting period beyond the pilot scale. Unless gas sales from this project are subsidised by the Canadian Government or promoted for a non-economic reason, little room is seen for this project in an oversupplied and low cost priced natural gas market before the turn of the century. However, with the anticipated design, construction and operation of the two ice-breaking LNG carriers, Canada will have established a degree of domination of such technology and thus will have increased its international reputation as an ice-ocean faring nation.

Table 7-10 shows the equipment forecast.

TABLE 7-10

PROJECT: ARCTIC PILOT PROJECT (APP) - LIQUIFIED NATURAL GAS
OPERATOR: PETRO CANADA
REFERENCE PROJECT DESCRIPTION: 7.6.1

CAPACITY (Incremental)	TIMING (Year)	EQUIPMENT REQUIREMENTS		
		TYPE	QUANTITY	SIZE
	1985	ICE-BREAKER CLASS 6	1	
		SUPPLY BOATS	2	
		CONSTRUCTION BARGE	1	
	1986	PROCESS BARGE	1	
		STORAGE BARGES	2	
		SUPPLY BOATS	2	
		ICE-BREAKER CLASS 4	1	
		OPERATIONS BARGE	1	
250 MMCFD	1987	LNG CARRIERS	2	125,000 m^3
		SUPPLY BOATS	2	

EQUIPMENT SUMMARY

LNG CARRIERS		2
ICE-BREAKERS	CLASS 6	1
	CLASS 4	1
PROCESS BARGES		1
STORAGE BARGE		2
CONSTRUCTION BARGES		1
OPERATIONS BARGE		1
SUPPLY BOATS		6

Another LNG project in the Arctic is the King Christian Island project which was announced by Trans-Canada Pipelines and Petro Canada in April, 1982. This will involve the German firm of Ruhrgas and Gelsenberg and could be expanded to more international firms.

The project plans to export LNG to several European countries. No timing has been given, but when using the history of some of Canada's major energy projects as a basis, a ten-year time span between conception and start-up could be expected.

For a capacity of 14 x 10^6 m^3/d (500 MMSCFD) of gas equivalent LNG and shipment to Western Europe, three or four LNG carriers of 125,000 m^3 capacity will be needed.

Assuming operations start-up by 1992, this project could well be seen to expand its capacity to one billion cubic feet of gas per day before the year 2000.

Table 7-11 lists the equipment and schedule needed for this project.

TABLE 7-11

PROJECT: KING CHRISTIAN ISLAND - LNG
OPERATOR: TCPL/PETRO CANADA/RUHRGAS/GELSENBERG
REFERENCE PROJECT DESCRIPTION: 7.6.1

CAPACITY (Incremental)	TIMING (Year)	EQUIPMENT REQUIREMENTS TYPE	QUANTITY	SIZE
	1990	ICE-BREAKER CLASS 6	1	
		SUPPLY BOATS	2	
		CONSTRUCTION BARGE	1	
	1991	LNG PROCESS BARGES	2	
		LNG STORAGE BARGES	4	
		SUPPLY BOATS	2	
		OPERATIONS BARGE	1	
500 MMCFD	1992	LNG CARRIERS	2	125,000 m^3
		SUPPLY BOATS	2	
	1993	LNG CARRIER	1	125,000 m^3
	1996	LNG CARRIER	1	125,000 m^3
		ICE-BREAKER CLASS 6	1	
		SUPPLY BOAT	1	
500 MMCFD	1997	LNG CARRIER	2	125,000 m^3
		PROCESS BARGES	2	
		STORAGE BARGES	4	

EQUIPMENT SUMMARY

LNG CARRIERS	6
ICE-BREAKERS (CLASS 6).	2
PROCESS BARGES	4
STORAGE BARGES	8
CONSTRUCTION BARGES	1
OPERATIONS BARGES	1
SUPPLY BOATS	7

The Canadian Arctic and East Coast has a very large potential for natural gas production and export to world markets as gas or LNG or chemicals, i.e., methanol or ammonia.

Because of the looming glut for all of these commodities, there is no market foreseen for they would be non-competitive. Therefore, no such energy projects in addition to those announced are considered for the forecasting period.

7.6.2 ARCTIC MINING PROJECTS

The hydrocarbon resources related projects may have captured the imagination of most; however, the existance of large gold, silver and lead zinc deposits in the Northwest Territories is factual, well known and commercial size mining operations are in place. The newest one ready for start-up at the end of this year, represents an investment of approximately $300 million. Cominco's Polaris lead zinc mine at Little Cornwallis Island, began production last year and is expected to reach full capacity late in 1982 or early 1983. Its design capacity is 2,000 t/d. The Polaris mine is surrounded by frozen seas for most of the year. This is why Cominco plans that during early years of operation, it will be able to ship its products only during one out of twelve months of the year.

Cullaton Lake Gold Mines Ltd., began operating its gold mine in the Keewatin district late in 1981.

An additional two gold mines are expected to begin production in the near future - Cominco's operation near Yellowknife and Echo Bay Mines project at Contwoyto Lake.

Also expected to start production during 1982 is Cadillac Exploration's silver and lead zinc mine in the Northwest Territories.

These commercial operations, in addition to continuing survey and exploration work in the Arctic will require an increased capability to travel the ice-bound straits and leads, as well as develop a year-round bulk shipping capability. To assist it, the Federal Cabinet is expected to give the green light for the Canadian Coast Guard project of the fabrication of the 100,000 h.p. Polar 8 Ice-breaker.

While the Coast Guard sees the main application of this newest and most sophisticated as well as the most powerful ice-breaking vessel of its fleet, in the emerging oil and gas industry activities, primarily in the Beaufort Sea and the Arctic Islands area, it may well turn out that during this decade and the early 1990's, the Polar 8 Ice-breaker will also assist the smaller, but commercially active mining operations in the N.W.T. This vessel will be capable of operation in the area for about eleven months per year in accordance with the Class 8 regulations.

At this time, the Coast Guard is hoping for a vessel completion by 1987/88, given approval by Cabinet in Summer, 1982. Future plans include the possible construction of a Polar 10 vessel, primarily for year-round operation in the Sverdrup Basin, and available for operation in the mid-1990's.

While few definitive plans for future mining projects exist at this time, a need for additional specifically designed and constructed vessels is foreseen. Ice-reinforced barges for housing of processing facilities and storage for products, to be built in southern shipyards and towed into place will be required. They will be similar to those currently planned for the Arctic Pilot project. Additionally, ice-reinforced tug boats for the towing operations will also be required. Furthermore, the transportation of products to market is envisaged to take place in bulk carrying barges with an ice-breaking capacity, as well as self-propelled ice-breaking bulk carriers.

Table 7-12 is the equipment forecast for the area.

TABLE 7-12

PROJECT: ARCTIC MINING PROJECTS
OPERATOR: UNDETERMINED AND CANADIAN COAST GUARD
REFERENCE PROJECT DESCRIPTION: 7.6.2

		EQUIPMENT REQUIREMENTS		
CAPACITY (Incremental)	TIMING (Year)	TYPE	QUANTITY	SIZE
	1986	PROCESS/STORAGE BARGES	2	
	1988	CCG ICE-BREAKER POLARIS 8	1	
	1990	PROCESS/STORAGE BARGES	2	
	1994	PROCESS/STORAGE BARGES	2	
	1996	CCG ICE-BREAKER POLARIS 10	1	
	1998	PROCESS/STORAGE BARGES	2	

7.7 HUDSON'S BAY

Exploration activity in the Hudson's Bay area was begun in the mid-1960's and concluded in the early 1970's after disappointing results. However, a consortium including the Ontario Government, the Quebec Government's Oil and Gas Development Company "Soquip", and two private industry companies announced in 1981, the beginning of further exploration in the area. For lack of information upon which a forecast of future exploration and production activities could be made, this area of potential hydrocarbon resources is not considered further in this forecast, however, any drilling would be done with semi-submersible rigs brought in from international/Canadian suppliers.

7.8 BRITISH COLUMBIA COAST

The ten year Exploration Moratorium is still in effect; however, in 1981, activities on governmental and industry levels indicated an interest to begin exploration on a more serious level. It can be anticipated though, that another Provincial/Federal confrontation will occur, since the B.C. Government, through installation of its Offshore Development Office, has given notice that it expects to own the offshore resources entirely.

Modest exploration activity in the waters off Vancouver Island and the northern B.C. coast are expected for this decade. During the 1990's, early production systems for oil and/or gas could be anticipated, producing possibly up to 40,000 m^3/d (250,000 b/d) from 1995 onwards.

The relevant project and equipment requirements are identified in Table 7-13.

The West Coast is an earthquake prone area and would likely see only floating systems for exploration and production. While the guyed tower concept is tested off California, overall for application in deeper waters at the West Coast, it is considered less suitable.

Semi-submersible rigs of high deck loading capacity could be converted to production systems. They, and supporting vessels including tankers, would not require any ice-reinforcing.

TABLE 7-13

PROJECT: WEST COAST OIL AND GAS EXPLORATION AND PRODUCTION
OPERATOR: B.C. CROWN CORPORATION, PETRO CANADA
REFERENCE PROJECT DESCRIPTION: 7.8

CAPACITY (Incremental)	TIMING (Year)	EQUIPMENT REQUIREMENTS TYPE	QUANTITY	SIZE
	1986	SEMI-SUBMERSIBLE	1	Class 4000
	1988	SEMI-SUBMERSIBLE	1	Class 4000
	1990	SEMI-SUBMERSIBLE	1	Class 4000

7.9 PROJECT EQUIPMENT SUMMARY

A total of 185 major pieces of equipment in 12 equipment categories will be procured during the forecasting period for the identified nine major project areas. Table 7-14 summarizes the forecasted equipment per project.

TABLE 7-14

PROJECT EQUIPMENT SUMMARY

	EAST COAST OIL & GAS EXPLORATION	HIBERNIA OIL PRODUCTION	HIBERNIA GAS PRODUCTION	SABLE ISLAND GAS PRODUCTION	DOME BEAUFORT OIL EXPLORATION/ PRODUCTION	ESSO/GULF BEAUFORT OIL EXPLORATION/ PRODUCTION	ARCTIC LNG PROJECTS	ARCTIC MINING PROJECTS	WEST COAST OIL & GAS EXPLORATION/ PRODUCTION	TOTAL
SUPPLY BOATS	5	10	2	6	12	7	13			55
DRILLING SEMI'S	5								3	8
PRODUCTION OR PROCESSING SEMI'S		3	1							4
STORAGE SEMI'S		3	1							4
TANKERS (OIL)		8			10	4				22
TANKERS (LNG)			1				8			9
STEEL PLATFORMS				3						3
BARGES*					16	8	19	8		51
STEEL CAISSONS					2	1				3
ROUND DRILLSHIPS					3	1				4
ICEBREAKERS					9	3	4	2		18
DREDGES					4					4

* Including Barges for Construction, Operation, Processing, Storage and Drilling.

8. EXPLORATION/PRODUCTION/TRANSPORTATION SYSTEMS TECHNOLOGY

8.1 ENVIRONMENTAL CONDITIONS IN FRONTIER AREAS

Environmental conditions are of importance for equipment design and operation. The four key parameters are:

- wind speed;
- wave height and characteristic period;
- current at surface and below;
- tide difference.

In addition to ice-floe, iceberg and ice-sheet movement or formation, these conditions represent the basis of system designs for the Canadian East Coast and Eastern Arctic areas.

The environmental influences in the Beaufort Sea and Arctic Islands areas differ greatly in that the water is frozen over for the better part of the year with a great number of ice-floes of varying sizes present during the open water shipping season, particularly so in the Beaufort Sea. The very active ice movement can subsequently move any system frozen in the ice sheet to the extent of several meters per year.

Deviations from both of these major environmental scenarios exist in other Canadian areas of interest such as the Scotia Shelf which is free of ice-floes and icebergs as is the British Columbia Coast.

Table 8-1 lists environmental parameters for each major project area.

TABLE 8-1
ENVIRONMENTAL PARAMETERS

ARCTIC ISLANDS

PARAMETER	VALUE(S)
Air Temperature:	Extreme temperatures range from -52°C to 16°C, with an annual mean daily -16°C (conditions for Resolute).
Wind:	Maximum wind speed: 39 m/s, maximum gust 46 m/s. Mean annual frequency of wind $\geq$ 14 m/s: 4.5% (for Resolute)
Water Temperature:	Upper 30 m range from -1.5°C to 5°C. Between 30 m and 250 m - 1.75°C to -0.25°C.
Current:	Variable. Maximum observed current 4 m/s in Bellot Strait.
Tide:	Tide range decreases from a maximum of 2 m in Jones Sound (in S.E.) to approximately 0.3 m in the N.W.
Wave Conditions	Most waves <1 m and maximum wave height is approximately 4 m.
Ice:	Waters completely covered by sea ice 7-10 months of the year. First year ice 2-3 m thick, multi-year up to 5 m. First year ridges up to 5m sail and keels up to 35 m. Maximum dimensions of multi-year ridges 3 m sail and 15 m keel. Ice islands present, but icebergs infrequent, scouring seen in inter-island channels.

Table 8-1 Continued/......

THE BEAUFORT SEA

Air Temperature:	Extremes range from -46°C to 27°C with an annual mean of -11°C.
Wind:	Average 5 m/s, but can have sustained values of 31 m/s and gusts to 39 m/s.
Water Temperature:	N/A
Current:	On the continental shelf, average value .3 m/s, with maximum of .6 m/s.
Tide:	Normal 0.5 m, storm up to approximately 3 m (one in 25 year event).
Wave Conditions:	Maximum height approximately 7 m.
Ice:	Southern Beaufort Sea usually covered for 9 months of the year with ice. Undisturbed ice can reach thickness of 2.4 m in land fast zone. Multi-year ice: up to 4 m thickness. Free floating multi-year ridges have been observed with total height of 42 m. Ice islands and ice island fragments are also present, sea bed scouring prevalent. Movement of ice is a function of type and environmental conditions and varies from virtually zero (land fast ice) to over .5 m/s (moderate ice-floe high-wind driven). Average yearly speed in gyre is 0.03 m/s.

GRAND BANKS

Air Temperature:	Extreme temperatures range from -26°C to 31°C (once in 100 years).
Wind:	Maximum 1 hour mean 67 m/s; 10 minute mean 72 m/s; 3-second gust 93 m/s.

Table 8-1 Continued/....

GRAND BANKS

Water Temperature:	Surface water varies from 17°C to -3°C.
Current:	Maximum surface 1.5 m/s; maximum bottom 0.5 m/s.
Tide:	N/A
Wave Conditions:	Maximum height approximately 34 m; significant height 17m; period 14 to 18 s.
Ice Conditions:	Pack ice commonly occurs from late January to late May and is 1 m thick with rafting on the edges of ice fields to 2 m. Icebergs present throughout year, but are mostly observed from May through July.

LABRADOR SHELF

Air Temperature:	Average daily varies from -20°C to +20°C.
Wind:	10 m/s, 40-50% of the time with 100 year wind speed of 36 m/s.
Water Temperature:	N/A
Current:	Variable, typical surface value 0.1 to 0.3 m/s with maximum of 1 to 1.5 m/s. Bottom currents up to 0.3 m/s.
Tide:	N/A
Wave Conditions:	Significant wave is higher than 3 m for more than 30% of the time with 100 year wave approximately 35 m.
Ice:	Ice cover from late November/December to mid-July. Icebergs are present all year round. Multi-year ice floes very numerous in winter. Iceberg scour observed in water depths exceeding 300 m. Typical ice velocity is 0.05 to 0.5 m/s with a maximum speed of 1.5 m/s.

Table 8-1 Continued/....

NORTH SEA (For Comparison)

Air Temperature: N/A

Wind: Maximum 3 s gust, 10 m above sea level 52 m/s.
Hourly mean speed 10 m above sea level 38 m/s.

Water Temperature: N/A

Current: Surface 1.4 m/s; at 15 m above sea bed 0.5 m/s.

Tide: Maximum 2.5 m.

Wave Conditions: Maximum wave height 30 m; Significant wave height 18.5 m; Characteristic Period 15 s.

8.2 SYSTEM CATEGORIES

8.2.1 BACKGROUND

Since the mid-1950's, offshore oil production has moved gradually into deeper waters, rapidly increasing costs. Exploration technology has improved to the extent permitting successful well completions in water depths of up to 1,300 m. Production technology for depths up to 300 m is currently proven.

Bottom supported platforms are used in water depths of over 360 m to support drilling and production facilities. Transportation of oil and gas to shore is by pipeline, environmental conditions permitting, or oil is loaded on to tankers and shipped to market. For the production of oil, subsea completion systems connected to single point mooring and loading systems of various adaptations are also used increasingly. Floating production systems, however, are being developed for a greater variety of applications. These systems should permit production from water depths of up to 1,000 m, using platforms supported by the tension leg method or by the guyed tower concept or by the articulated buoy system.

Most offshore exploratory drilling at present in water deeper than 100 m is carried out from moored floating vessels. They include ships, barges and semi-submersibles of various designs which have been used successfully in water depths of over 1,300 m. Floating vessel concepts are also used to drill development wells in connection with subsea production systems.

Offshore storage systems are currently used in many different concepts including floating, resting on the sea bottom and attached to production platforms. Also, the vertical storage column concept has been developed and is used in the North Sea.

While the identified systems all relate to the liquid environment, systems for exploration, production, storage and trans-shipment to tankers in the ice-infested Arctic differ greatly. There, the two major versions of exploration platforms are the artificially thickened ice islands and the sand island using material dredged from the sea bottom. In the region of the Arctic Islands, natural gas will be produced using subsea completion techniques in connection with pipeline transportation to the mainland. In the southern Beaufort Sea, however, it is envisaged that the dredged sand islands will, for the purpose of production, be reinforced with concrete or steel caissons.

For the purpose of illustration, Figure 8-1 shows the conventional depth range of drill vessels including jack-up, semi-submersible and ship.

In the following subsections, the systems are categorized; detailed descriptions are in Appendix A.

8.2.2 SYSTEM DESCRIPTIONS

Jack-Up Rigs - are self elevating drilling rigs that have the mobility to float to the exploration site where they extend their legs, usually three, to the sea bottom and lift the platform above sea level. Recent developments have increased size, water depth capability and the ability to propel itself to desired sites, even in unprotected open water.

FIGURE 8-1

OPERATING PROFILES OF SOME
OFFSHORE DRILLING PLATFORMS

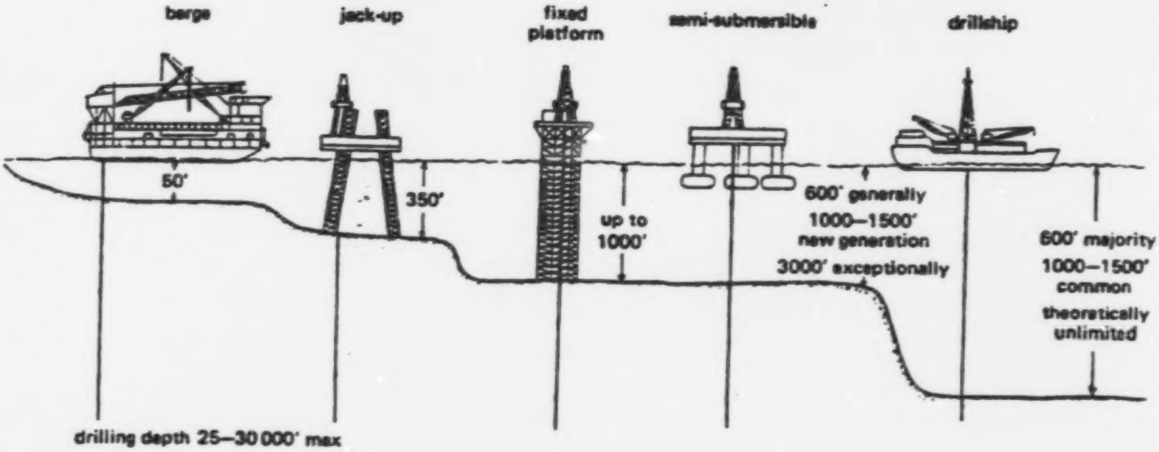

barge
jack-up
fixed platform
semi-submersible
drillship
50'
350'
up to 1000'
600' generally
1000–1500' new generation
3000' exceptionally
600' majority
1000–1500' common
theoretically unlimited
drilling depth 25–30 000' max

Figure 8-2 shows a chronology of jack-up rigs from 1953 to 1969. The water depth capability of jack-up type rigs ranges to over 150 m, with the drilling capability of the largest of this species to depths of 8,200 m below sea level.

Floating Drill Rigs - include a variety of designs, the ship-shape vessel, barges and semi-submersible vessels. The application of floating vessels for offshore drilling dates back to 1953, when a drilling rig was cantilevered over the side of two ships to perform sea floor coring operations.

Barges usually are employed in very shallow waters, while semi-submersible drilling rigs are successfully used in water depths of up to 1,300 m. For deep water applications, ship-shape drill rigs are being used.

FIGURE 8-2
CHRONOLOGY OF JACK-UP RIGS, 1953-1969

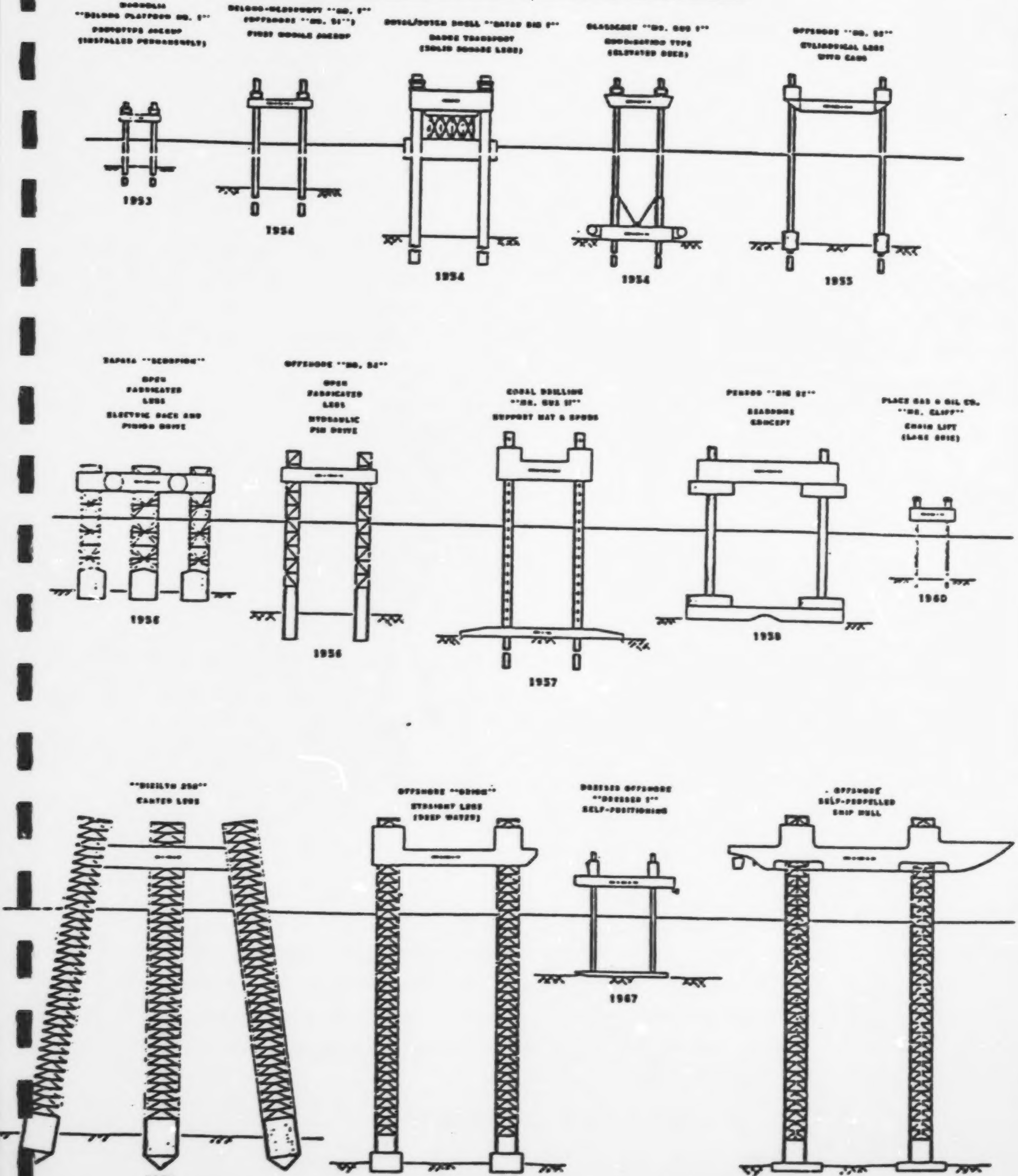

PROTOTYPE JACKUP
(INSTALLED PERMANENTLY)
1953
FIRST MOBILE JACKUP
1954
BARGE TRANSPORT
(SOLID SQUARE LEGS)
1954
GLASSCOCK ''MR. GUS I''
(ELEVATED DECK)
1954
OFFSHORE ''NO. 55''
CYLINDRICAL LEGS
WITH CANS
1955
ZAPATA ''SCORPION''
OPEN
FABRICATED
LEGS
ELECTRIC RACK AND
PINION DRIVE
1956
OFFSHORE ''NO. 52''
OPEN
FABRICATED
LEGS
HYDRAULIC
PIN DRIVE
1956
CORAL DRILLING
''MR. GUS II''
SUPPORT MAT & SPUDS
1957
CONCEPT
1958
''MR. CLIFF''
CHAIN LIFT
(LAKE ERIE)
1960
CANTED LEGS
1963
OFFSHORE ''ORION''
STRAIGHT LEGS
(DEEP WATER)
1966
DRESSER OFFSHORE
''DRESSER I''
SELF-POSITIONING
1967
OFFSHORE
SELF-PROPELLED
SHIP HULL
1969

Figure 8-3 shows a chronology of early floating rigs (up to 1968) including semi-submersible rigs.

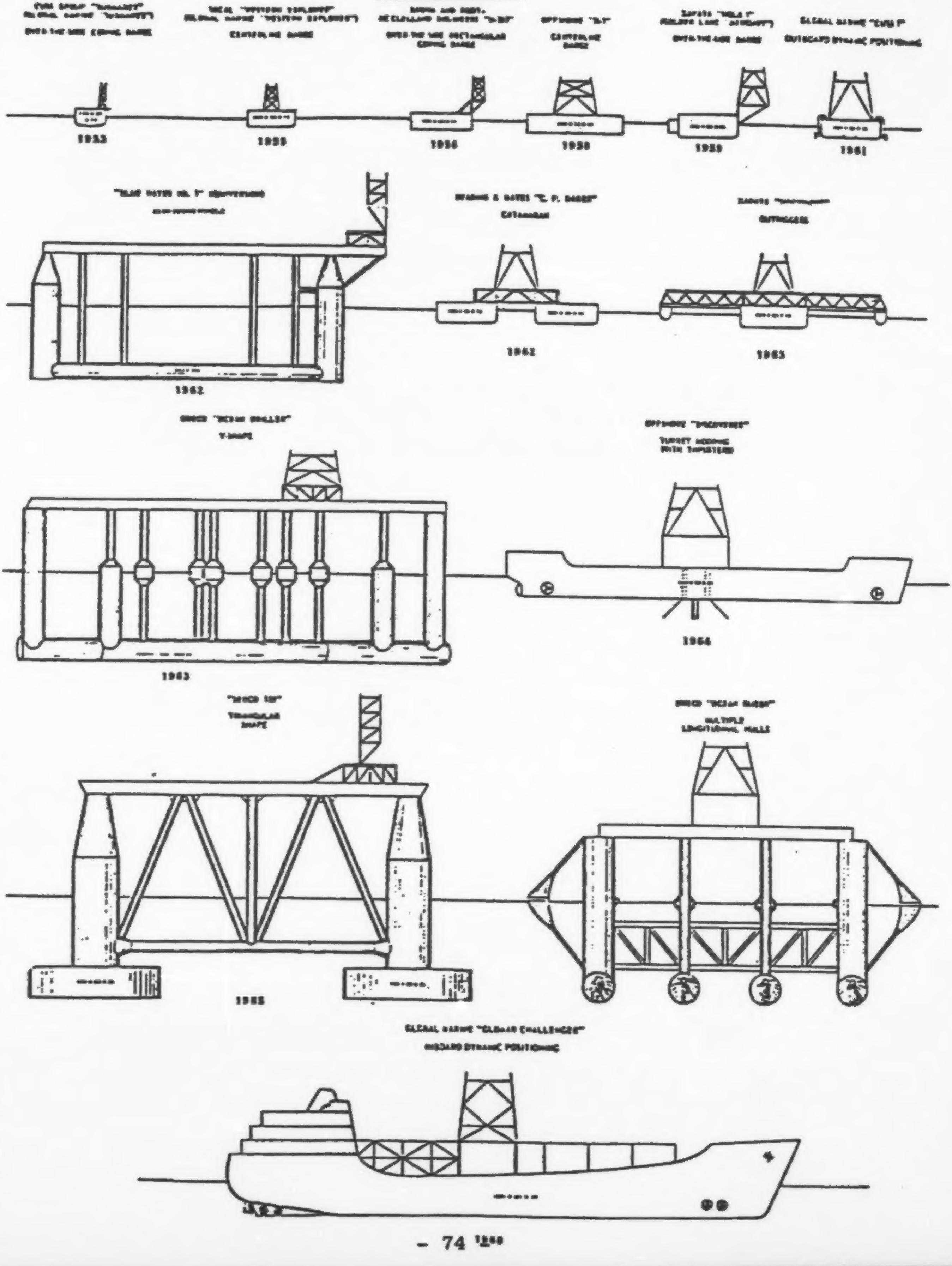
Semi-Submersible Rigs - are basically a hybrid combination of the submersible type structure and drillship and barge drilling operations. They are dynamically stable during transit and provide a stable platform for drilling or other operations. The advantage of these structures is their wave transparency, due to submerged buoyancy chambers which are connected to the elevated drilling deck by structural columns of low relative displacement volume. Semi-submersible platforms are most advantageously employed in very rough seas, and appear to be the most suitable drilling and also early production systems for East Coast Canadian operations because of their mobility, when self-propelled, to evade icebergs.

Production Systems come in basically three different concepts of which the gravity platform from steel was the first one used. They are mainly employed in the Gulf of Mexico and the North Sea in addition to other production areas all over the world. Commonly, these platforms are supported by a steel jacket that rests on the sea bed, with the decks located sufficiently high above the sea level to avoid impact by maximum waves.

Gravity Platforms from Concrete - have successfully been used in the North Sea area. In the Norwegian Sector, they represent a large percentage of production platforms. They differ from steel platforms, namely, being larger, using fewer individual structural

CHRONOLOGY OF FLOATING RIGS, 1953–1968

FIGURE 8-3


OVER-THE-SIDE CORING BARGE
1953
CENTERLINE BARGE
1955
OVER-THE-SIDE RECTANGULAR CORING BARGE
1956
CENTERLINE BARGE
1958
ZAPATA
OVER-THE-SIDE BARGE
1959
GLOBAL MARINE "CUSS I"
OUTBOARD DYNAMIC POSITIONING
1961
"BLUE WATER NO. 1" SEMISUBMERSIBLE
1962
READING & BATES "C. P. BAKER"
CATAMARAN
1962
ZAPATA
OUTRIGGERS
1963
ODECO "OCEAN DRILLER"
V-SHAPE
1963
OFFSHORE "DISCOVERER"
TURRET MOORING (WITH THRUSTERS)
1964
"SEDCO 135"
TRIANGULAR SHAPE
1965
ODECO "OCEAN QUEEN"
MULTIPLE LONGITUDINAL HULLS
GLOBAL MARINE "GLOMAR CHALLENGER"
INBOARD DYNAMIC POSITIONING

members, and are often supported on only three legs with little or no bracing between them. The Cook Inlet monopod could be the extreme representative of concrete gravity platform technology.

Floating Production Platforms - are mainly semi-submersible production platforms. Principally, they represent an extension of the semi-submersible drilling rig technology, but they are considerably larger to accommodate the greater deck loads of up to 15,000 and 20,000 tonnes (compared to 3,000 to 6,000 for drilling semi's). To date, only a few are in operation or are developing. State-of-the-art of control systems and large power systems permit their dynamic positioning.

The new generation of production platforms, particularly geared to water depths of up to 600 and 800 m, include the Tension Leg Platform, the Articulated Buoy Platform and the Guyed Tower Platform. Basically, the tension leg platform is a semi-submersible tethered with tension cables to anchors in the sea floor located directly beneath the platform.

In concept, the articulated buoy and guyed tower systems are related as they both consist of a slender column supported at the sea bottom with an articulated joint at the sea bottom and a buoy characteristic platform above sea level - (Articulated Buoy System), or with the top of the column guyed to anchors in the sea floor in the case of the guyed tower concept.

Processing Plants - although not yet in active service, they are planned to be located close to the production system and to represent an economical solution to transporting crude oil to refineries, instead of transporting refined products, particularly liquefied natural gas or methanol made from natural gas, to markets. The envisaged platform systems include semi-submersibles, barge type or ship-shape concepts.

The third major category of production systems is located at sea bottom. Subsea Production Systems are already being used successfully in areas where there is no danger to the installation from ship traffic or icebergs. Commonly, they include a template and a rather common technology type wellhead.

To effectively produce and transport oil and gas in liquid or gaseous state, storage and loading systems are required. Many of the larger production systems have sea bottom storage tanks attached to the structure to shave the peaks arising from constant oil production and intermittent transportation.

A variety of storage systems are in use, or are developing, including steel-based, concrete-based or rubber-based sea bottom storage tanks, which use ballast water for buoyancy control.

A unique system has evolved in the recent past, which includes subsea production and the storage of oil in a vertical cylinder that represents the riser from sea bottom to an oil loading facility to tanker.

The development of the Beaufort Sea introduced new equipment for virtually every phase of the development.

Artificial Sand Islands - can be used up to a water depth of 20 m. They pose neither technological nor great financial burden.

In water depths of up to 50 m, Caisson-Retained Artificial Islands are in use or are developing.

Floating Drilling Units - will be used in even greater water depths.

While these three systems will permit year-round drilling, the currently used drilling ships can be used only during the ice-free summer months and then are still vulnerable to high wind conditions and extensive ice-floe occurrence.

Systems to produce the oil and gas found in the Beaufort will likely include caisson or otherwise retained artificial islands, e.g., Arctic Production Loading Atoll (APLA), which will be bottom-supported and made up of a mixture of steel or concrete retainers and dredged sand. The initial tanker loading systems to be used in the early phases of oil and gas production will likely include single point mooring systems, yet highly modified for application in the Beaufort Sea.

The pipeline transportation mode for both oil and gas will likely be utilized as well, particularly for gas.

Arctic Vessels - include ice-breaking LNG carriers and crude oil tankers of various ice reinforcement classes, ice-breakers and a variety of multi-purpose or support vessels.

The exploitation of Arctic resources requires the use of processing plants on site, specifically in case of mining projects which will increasingly be barge-mounted, fabricated in the South and transported to the site and bermed or moored there.

The above identified systems are described in more detail, particularly relative to thick steel plate use in Appendix A.

9. MATERIAL REQUIREMENTS

9.1 BACKGROUND

Oil production equipment in cold climates must operate at much lower temperatures than normally encountered. For example, Arctic air temperatures can approach lows of -55°C (-70°F). Sea water reaches a temperature of 10°C (-28°F) and permafrost is at-2.3°C (14°F). API Standard 650 gives the lowest one day mean temperature isotherms for the United States and Canada for selecting design temperatures. It is necessary to design a structure for the lowest actual temperature rather than for a moderate seasonal average over many years. Structural steels can become brittle at low temperatures which can result in the catastrophic failure of expensive equipment with serious risk of personal injury, loss in production and damage to the environment. Fortunately, much has been learned about the fracture behaviour of steel since the first brittle failures of steel structures occurred in the late nineteenth century. Considerable research is still being conducted on the mechanisms of brittle crack nucleation and propagation. The field of fracture mechanics is undergoing continuous development and shows considerable promise for improved materials characterization as well as structure integrity analysis. Liquefied gas technology has led to the development of many steels with excellent resistance to brittle fracture at temperatures lower than those encountered in Arctic regions. However, these steels contain expensive alloying elements and, therefore, are not always economical choices for use at the more moderate Arctic temperatures. Interest in the economic development of the Arctic is presently directing effort towards improving the brittle fracture resistance of less expensive steels in the -18°C to -55°C temperature range.

Design and fabrication of offshore structures are governed by codes and regulations. Codes of practice and rules governing planning, design, construction, inspection and operation of offshore steel structures consist of the National Standard Codes dealing with conventional steel structures, rules and recommended practices on the offshore structures and rules and guidelines pertaining to Arctic and ice-infested areas. Examples of the conventional steel structures codes are:

- Canadian National Standard Code for Steel Structures - CAN3-A23-3-M77;
- British Codes of Practice - BS-449, 153;
- Manual of Steel Construction - American Institute of Steel Construction (AISC).

Documents dealing with offshore steel structures include:

- Rules for the Design, Construction and Inspection of Offshore Structures, 1977 - Det norske Veritas (Dnv);
- Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms, API RP2A 1981;
- Offshore Installations: Guidance on Design and Construction - British Department of Energy, H.M.S.O., 1977;

- Rules for Classification of Mobile Offshore Units, (Dnv), 1981;
- Code for the Construction and Equipment of Mobile Offshore Drilling Units (MODU Code), IMCO, London, 1981;
- Rules for Building and Classing Steel Vessels, American Bureau of Shipping - ABS, 1981.

There is currently no code of practice specifically dealing with Arctic offshore steel structures. However, the relevant stipulations of ABS and DnV rules for ice strengthening of vessels can be used as guidelines. In addition, the following documents are also available:

- Arctic Shipping Pollution Prevention Regulations, Canadian Department of Transportation, (ASPPR - 1972-1979);
- API Bulletin for Planning, Designing and Constructing Fixed Offshore Structures in Ice Environments, May, 1981.

Design and fabrication of a structure are equally important as are the properties of the materials selected to obtain adequate resistance to brittle fracture. Designs should attempt to minimize severe stress concentrations and high biaxial and triaxial stresses, especially in thick sections; however, if this is unavoidable, it must be ensured that the through-thickness ductility is adequate. The quality of fabrication should be good to eliminate defects that could act as brittle crack nucleators or propagate under service stresses. The discussion that follows pertains to the principal factors that determine the properties of and demand for thick plate steel that may be selected for Arctic offshore application.

9.2 THICK STEEL PLATE REQUIREMENTS (t>25 mm)

Thick plate is likely to be required for the following components of offshore steel structures and vessels:

- piling and main legs of fixed steel jackets manufactured by rolling plates to form large diameter cylinders;
- braces and can joints in fixed steel platforms;
- column stabilizers of mobile units;
- skin plates of fill-retaining steel caissons;
- wellhead chambers in subsea production systems;
- steel decks designed as plate or box girders;
- stiffeners for skin plating, webs, etc.

The extent and properties of thick plates in an offshore structure will, of course, depend on the environmental conditions and functional requirements which the structure will eventually encounter. Published information on the existing structures is usually confined to generalities and lacks details on plate thicknesses and distribution of steel weight vis-a-vis thickness. However, it is very likely that the use of thick plates will be extensive in steel structures for ice-infested offshore areas considering available data on designed systems, loading conditions and the requirements of the relevant codes and regulations.

9.3 STRENGTH AND STIFFNESS REQUIREMENTS

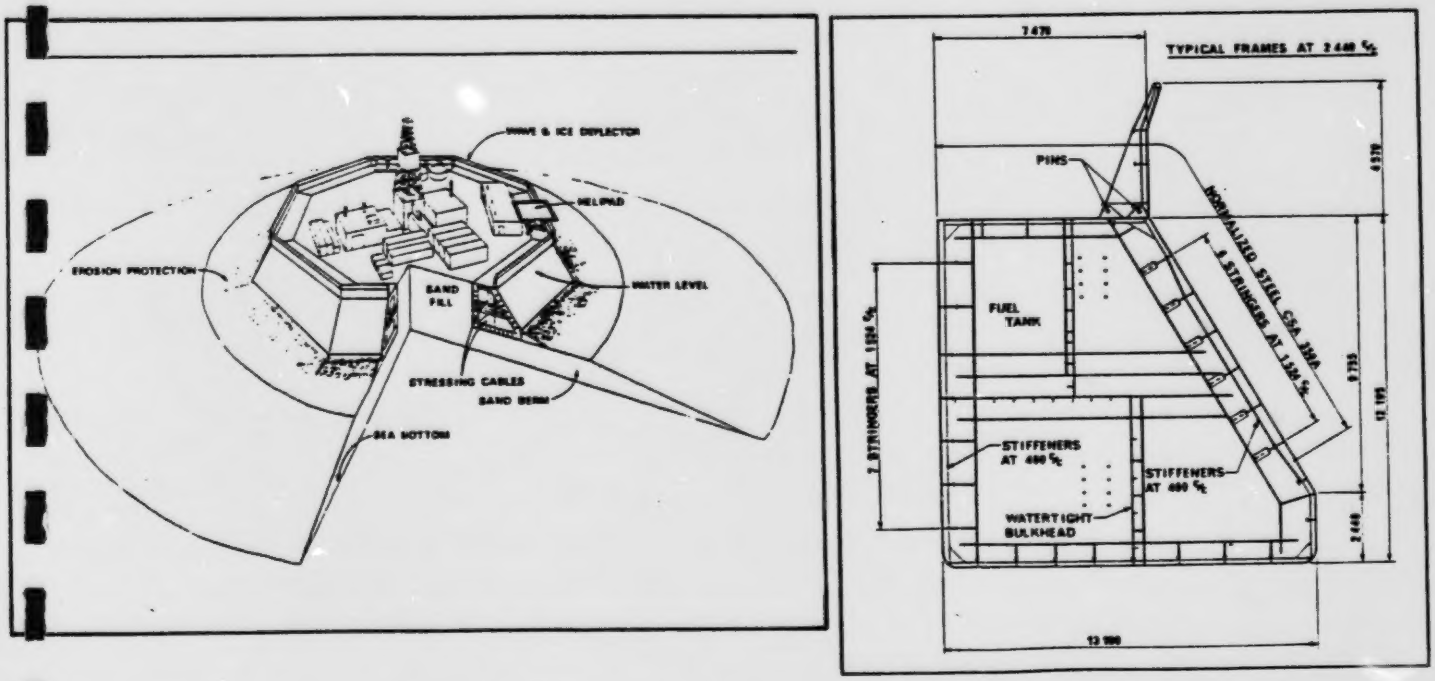
The skin plate thickness of steel caissons or ice-breakers developed for operation in the Beaufort Sea is determined by the intensity of local ice pressures and the spacing of stiffeners. The local ice pressure that is to be used in the design of structures is a contentious issue and some experts believe that local pressures that have been used in some recent designs are low. ASPPR specifies a local ice pressure of 10.34 MPa for the most critical sections of Class 10 Arctic vessels. It is unlikely that the spacing of stiffeners is less than 400 mm. For local ice pressures of the order of magnitude stipulated by ASPPR and yield strength of 350 MPa plate, thickness would not be less than 30 mm even if the beneficial membrane action was accounted for in design. Assuming an average thickness of 30 mm for the face and back walls, total weight of thick plates for the steel caisson shown in Figure 9-1 will be about 1800 tonnes which is 22% of the total weight. (Pullerits, K., 1982). This is only an estimate which completely ignores that thick plates may have been used in other components of the caisson and that the average thickness may have been more than 30 mm. Another factor which may increase the thickness requirements is that skin plate is usually required to have some reserve of strength to participate as flanges of web frames to resist global ice loading which may be acting on the caisson in conjunction with the local pressures.

In fixed steel platforms that have been installed in the Gulf of Mexico and the North Sea, which when ice strengthened, may be applied in the East Coast offshore areas, thick plates are used principally for piles, main platform legs and can joints.

In the North Sea at water depths of 100 to 200 m, skirt piles are used in clusters of twelve. Typical pile diameters range from 1.37 to 1.83 m and the wall thickness from 51 to 63 mm, so that the weight of each pile can be as much as 2.9 tonnes per meter. It is not only strength

FIGURE 9-1

ARCTIC ISLAND STEEL CAISSON


WAVE & ICE DEFLECTOR
HELIPAD
EROSION PROTECTION
WATER LEVEL
SAND FILL
STRESSING CABLES
SAND BERM
SEA BOTTOM
7 470
TYPICAL FRAMES AT 2 440 c/c
PINS
NORMALIZED STEEL CSA 350A
8 STRINGERS AT 1 524 c/c
4 570
FUEL TANK
7 STRINGERS AT 1 524 c/c
9 735
12 195
STIFFENERS AT 400 c/c
STIFFENERS AT 400 c/c
WATERTIGHT BULKHEAD
2 440
13 900

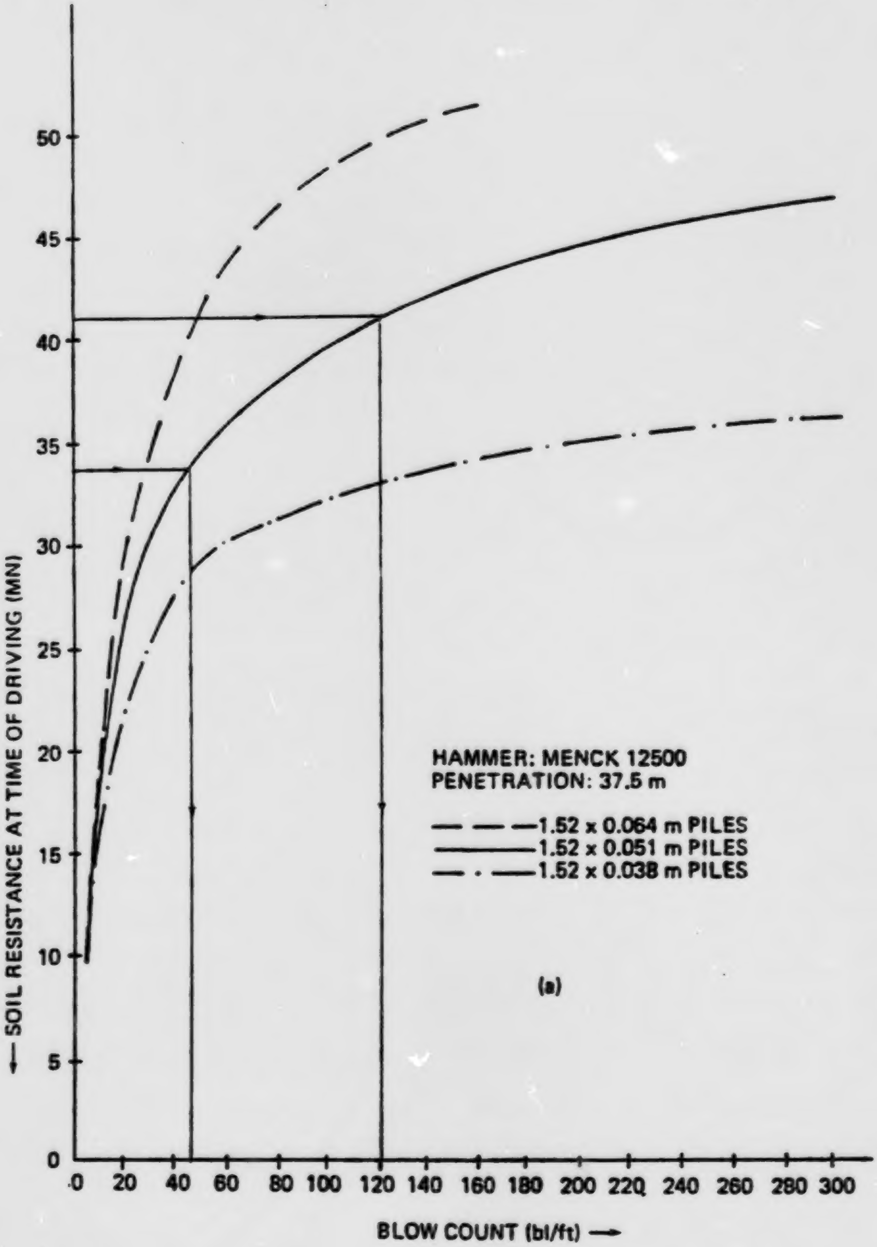
Source: (Pullerits, K., 1982)

requirement that determines the wall thickness, but also the driveability which is significantly increased with thickness as shown in Figure 9-2 (POAC 79, Volume 2). This diagram illustrates that for a given soil resistance, much less energy is required to drive the pile into the ground as pile thickness is increased from 38 to 64 mm.

As the main legs of a steel platform function structurally as beam columns, it is essential that local buckling does not undermine the overall strength of the member. Hence, API and DnV recommend the following limitations:

FIGURE 9-2

Source: (POAC 79, Volume 2).



BLOW COUNT vs DRIVING RESISTANCE
FOR PILES OF DIFFERENT
WALL THICKNESS.

$$D/t < 0.1 \frac{E}{\sigma_y} \quad \text{(API)}$$

$$D/t < 0.056 \frac{E}{\sigma_y} \quad \text{(DnV)}$$

where σ_y and E are the yield stress and Young's modulus of the steel used. Assuming $\sigma_y = 350$ MPa and taking E = 200,000 MPa, the range of leg diameters for wall thickness greater than 25 mm will be as follows:

For D >1.46 m; t >25 mm (API)
D >0.813 m; t >25 mm (DnV)

Leg diameters larger than 1.5 meters are used extensively in offshore template steel structures which implies that the legs are in the main fabricated from thick plates. Furthermore, thicker plates will also be specified to enhance ice-impact energy absorption capacity in ice-infested areas. An estimate of the weight of thick plates required for a North Sea platform can be made on the basis of published information. The model structure is a piled steel tower installed in 168.5 meters of water in the Ninian Field of British North Sea, and the following details have been extracted from OTC paper 3148 (1978):

- Pile plate thickness = 63 mm
- Weight of steel jacket = 18,000 tonnes
- Weight of piles = 6,900 tonnes.

Assuming legs and joint cans to have a weight equal to 40% of tower weight, the total thick plates required are 14,000 tonnes. This is about 56% of the total steel weight. These estimates give an indication of the quantities of thick steel plates required per platform. The total requirement will, of course, depend on how many platforms of each type are required, which in turn, is a function of the development programs of the operators. For example, it has been suggested that 100,000 b/d of oil could be produced from 7,000 acres in the Hibernia area by using two floating production platforms (Motyka, D.R. and Hnatiuk, J., 1981).

9.4 DUCTILITY AND FRACTURE TOUGHNESS

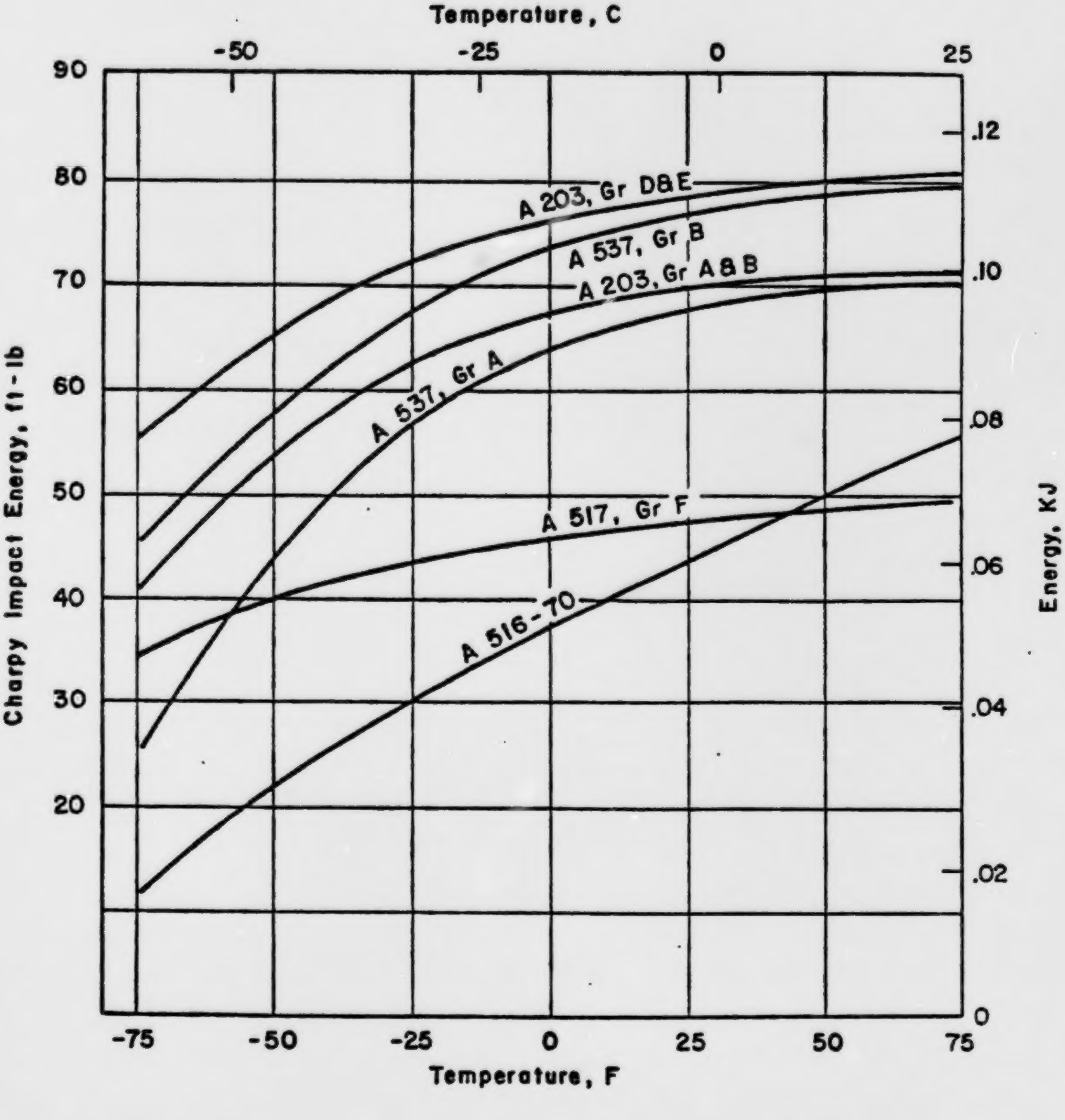
Steel used for offshore steel structures must satisfy the requirements of strength, notch toughness, corrosion resistance, weldability, formability and through-thickness ductility. The possible modes of failure normally designed against are brittle and ductile fracture, excessive deflection, buckling, fatigue, corrosion fatigue and lamination. Steel requirements for conventional offshore steel structures are stipulated in codes and rules such as ABS, API and DnV. Thick steel plates under Arctic environmental conditions require special properties which are discussed below.

Both increasing the thickness and reducing the temperature dramatically reduce the toughness of steel. The reduction in toughness, as expressed in terms of Charpy impact energy is shown for various types of steel in Figure 9-3. However, these curves apply to steel plates up to 25.4 mm. Reduction in toughness with thickness is illustrated in Figure 9-4.

The significant dependence of fracture toughness on thickness is reflected in codes and regulations. For example, DnV's Rules for Fixed Structures require:

FIGURE 9-3

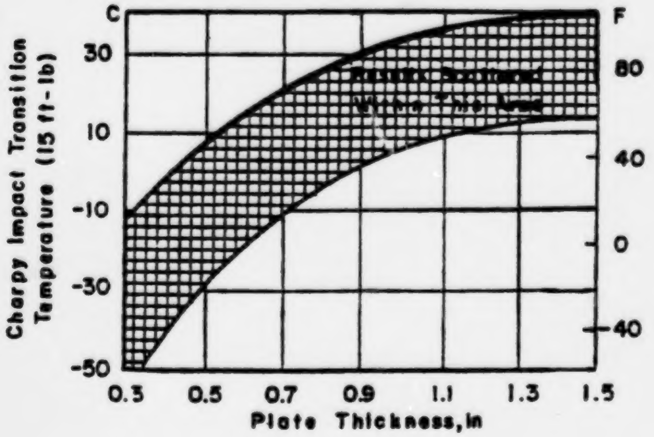
CHARPY IMPACT TRANSITION BEHAVIOUR OF ASTM PLATE STRUCTURE



Source: (ASM Book on Materials Selection, Vol.1, 1977).

FIGURE 9-4

EFFECT OF PLATE THICKNESS ON THE CHARPY IMPACT TRANSITION TEMPERATURE OF MILD STEEL



Source: (ASM Book on Materials Selection, Volume 1, 1977).

Toughness Testing

Charpy V-Notch with service experience. Fracture mechanics such as COD for heavy joints and no previous documented experience.

Toughness Requirements

Charpy impact energy increasing from 27 to 30 joules as steel yield stresses range from 275 MPa to 390 MPa.

Impact Testing Temperature

Thickness (mm)	Special Steel	Primary Steel	Secondary Steel
$t < 12.5$	$T=T_D$	$T=T_D$	
$12.5 < t < 25.5$	$T=T_D-20$	$T=T_D$	
$25.5 < t < 50.0$	$T=T_D-40$	$T=T_D-20$	$T=T_D$
$t > 50.0$	$T=T_D-40$	$T=T_D-40$	$T=T_D-20$

T = Impact Testing Temperature (°C); and, T_D = Design Temperature (°C).*

Examples of special structural steel are in joint cans and deck to leg connections. Primary structural steel is used for jacket legs, piles, bracing etc; secondary steel is used in deck members. The specification for thick plate could require either a lower transition temperature for a given loading energy or a higher loading energy for a given transition temperature.

The environmental temperatures in the Arctic can be as low as -50°C and the water temperature -2.3°C. Hence, thick plates at the splash zone of a fixed steel structure should exhibit the required toughness at a temperature of -70°C if it is assumed that the minimum monthly mean temperature is -25°C . It should also be noted that cold forming used to fabricate large diameter cylinders from thick plates reduces toughness. This establishes the steel selection toughness criterion.

Specification of the required toughness to preclude the possibility of brittle fracture does not imply that the steel is available. Figure 9-5 lists a range of steels that possess the necessary toughness at the low service temperatures shown, but these only apply if thickness does not exceed 25.4 mm. Table 9-1 lists a range of steels for low temperatures which include cryogenic steels.

* Minimum monthly mean air temperature minus 5°C .

FIGURE 9-5

ASTM PLATE STEELS FOR LOW TEMPERATURE SERVICE

Source: (ASM Book on Materials Selection, Vol.1, 1977).

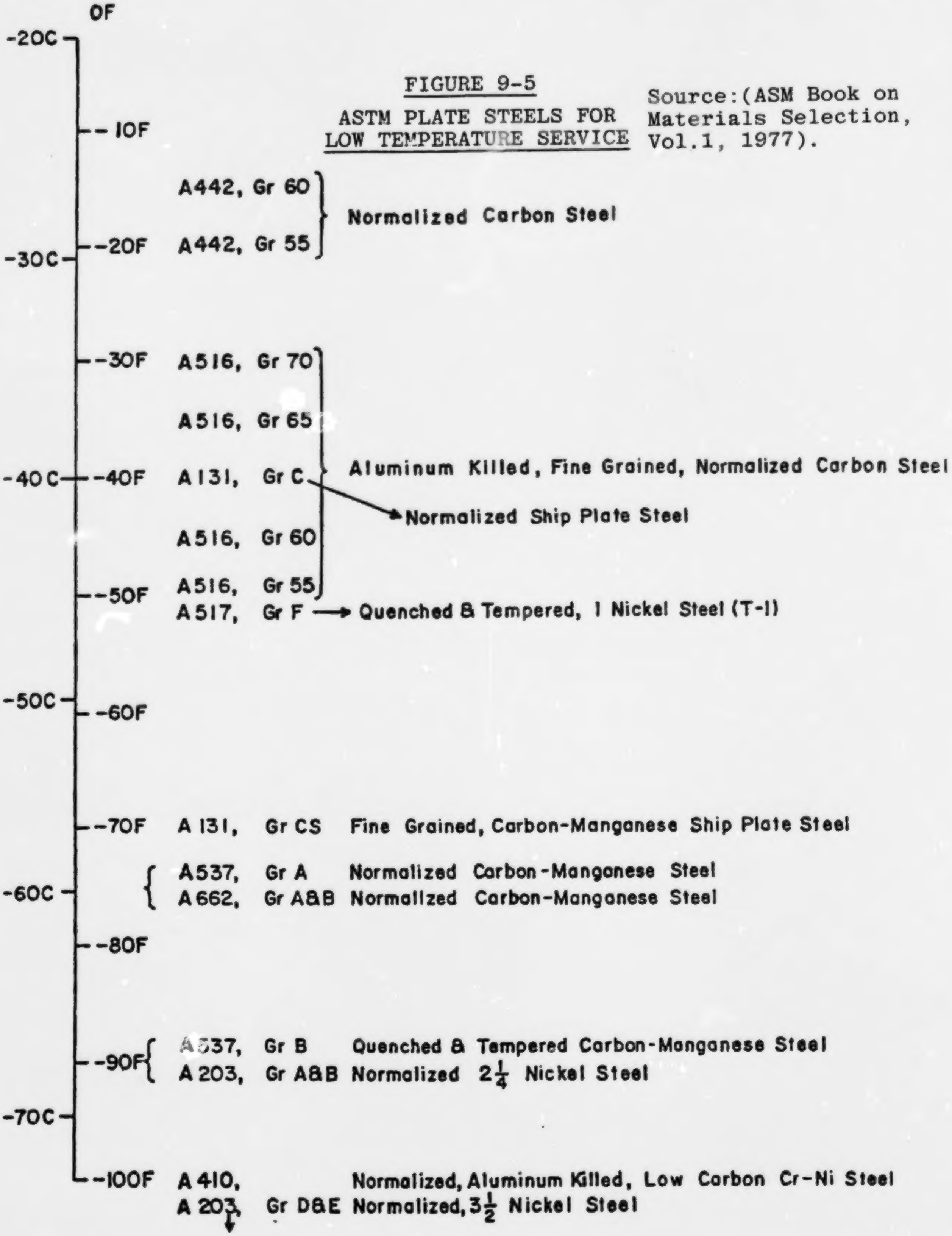

0F
-20C
-10F
A442, Gr 60
A442, Gr 55
Normalized Carbon Steel
-30C
-20F
-30F
A516, Gr 70
A516, Gr 65
Aluminum Killed, Fine Grained, Normalized Carbon Steel
-40C
-40F
A131, Gr C
Normalized Ship Plate Steel
A516, Gr 60
A516, Gr 55
-50F
A517, Gr F
Quenched & Tempered, 1 Nickel Steel (T-1)
-50C
-60F
-70F
A 131, Gr CS Fine Grained, Carbon-Manganese Ship Plate Steel
A537, Gr A Normalized Carbon-Manganese Steel
-60C
A 662, Gr A&B Normalized Carbon-Manganese Steel
-80F
A537, Gr B Quenched & Tempered Carbon-Manganese Steel
-90F
A 203, Gr A&B Normalized 2$\frac{1}{4}$ Nickel Steel
-70C
-100F
A 410, Normalized, Aluminum Killed, Low Carbon Cr-Ni Steel
A 203, Gr D&E Normalized, 3$\frac{1}{2}$ Nickel Steel

TABLE 9-1
SPECIFICATIONS FOR LOW TEMPERATURE STEELS

Designation	Lowest Usual Service Temperature, F	Min Yield Strength, Psi	Tensile Strength, Psi	ASME Allowable Stress, Psi*	Min Elongation, %		Uses
					2 in.	8 in.	
ASTM A442—Gr. 55	—50	30,000	55,000-65,000	13,750	26	21	Welded pressure vessels and stor age tanks; refrigeration; transpor equipment.
—Gr. 60	—50	32,000	60,000-72,000	15,000	23	20	
ASTM A516—Gr. 55 †	—50	30,000	55,000-65,000	13,750	27	23	
—Gr. 60 †	—50	32,000	60,000-72,000	15,000	25	21	
—Gr. 65 †	—50	35,000	65,000-77,000	16,250	23	19	
—Gr. 70 †	—50	38,000	70,000-85,000	17,500	21	17	
AAR TC-128--Gr. B †	—50	50,000	81,000-101,000	20,250	21	18	Railroad tank cars.
ASTM A517—Gr. F	—50	100,000	115,000-135,000	28,750	16	—	Highly stressed vessels; tank truck for LP gases.
Lukens LT-75-HS(≦¾ in.)	—75	75,000	95,000-115,000	23,750	19	—	Offshore drilling platforms; low-temperature environment structures; earthmoving equipment; storage tanks.
ASTM A537—Gr. A (≦ 1¼ in.)	—75	50,000	70,000-90,000	17,500	22	18	
—Gr. B (≦ 1¼ in.)	—75	60,000	80,000-100,000	20,000	22	—	
ASTM A203—Gr. A	—75	37,000	65,000-77,000	16,250	23	19	Tanks, vessels, and piping for liquid propane.
—Gr. B	—75	40,000	70,000-85,000	17,500	21	17	
—Gr. D	—150	37,000	65,000-77,000	16,250	23	19	Land-based storage of liquid propane, carbon dioxide, acetylene. ethane, and ethylene.
—Gr. E	—150	40,000	70,000-85,000	17,500	21	17	
ASTM A533—Class 1	—100	50,000	80,000-100,000	20,000	18	—	Nuclear reactor vessels where low ambient toughness required for hydrostatic testing; some chemica and petroleum equipment.
—Class 2	—100	70,000	90,000-115,000	22,500	16	—	
—Class 3	—100	82,500	100,000-125,000	25,000	16	—	
ASTM A543—Class 1	—160	85,000	105,000-125,000	26,250	14	—	Candidate material with high notc toughness for heavy-wall pressure vessels.
—Class 2	—160	100,000	115,000-135,000	28,750	14	—	

Source: Book on Materials Selection, Vol. 1, ASM, 1977.

It would be uneconomic to incur high cost of cryogenic steels because the toughness requirements for offshore steel structures are not as stringent. Before steels in Table 9-1 can be selected, the thickness limitations must be identified. Changes in steel composition that enhance toughness usually alter formability and weldability and data on these changes will also be needed for proper steel selection.

It should be noted that modifications of the existing steels may well produce the desired properties for thick plates, but this must, of course, be established. In fact, one major Canadian steelmaker claims that its TA range possesses the Arctic characteristics. No quantitative data is, however, available to assess this claim. The steel caissons that are being built for installation in the Beaufort Sea use steels that are modifications of the existing ship or bridge steels.

In the light of the considerable potential demand for thick steel plates that meet the requirements for Arctic application, the following recommendations are made:

1. Establishment of a maximum plate thickness for critical regions. This could be about 50 mm, for beyond certain thicknesses it may become economically unfeasible to obtain the required toughness at $-50^{o}C$.
2. Development of new, or adaptation of the existing steel compositions that possess the required toughness, without being too tough if this increases the cost. This involves fracture mechanics and Charpy impact tests.
3. Tests to establish formability and weldability, fatigue and corrosion resistance of the steels developed. Tests on through-thickness ductility will also be necessary.
4. Tests on realistic tubular node and other connections using the steels to determine the flaw size effect on toughness. It is known that PWHT effectively compensates the loss of toughness due to increase in thickness. This needs verification for the steels under consideration.

9.5 WELDING AND THE INTEGRITY OF JOINTS

Apart from several highly specialized individual fabrication techniques and procedures, the majority of offshore structures and ships are fabricated by common and proven methods. When involving standard steels, typical steel jacket type offshore structures or jack-up rigs use metal cutting, forming and welding techniques for tubular products and steel sections and beams requiring very little new or unusual input. The same is true for the building of vessels for Arctic application. Typical bulkhead, stringer and flange type construction are used in all of the hull fabrication.

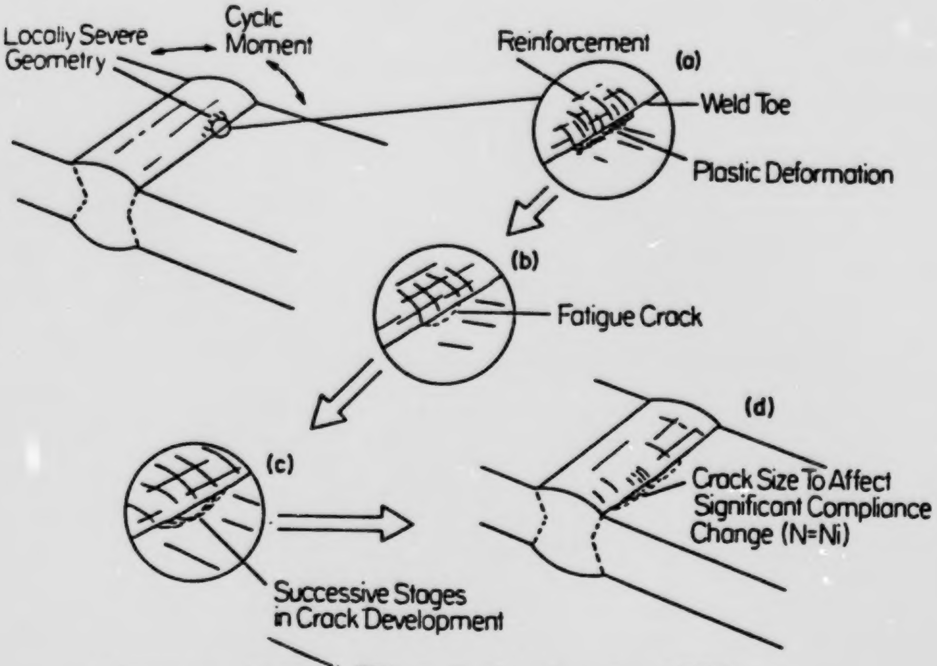
Methods and procedures, of course, change when high tensile low alloy steels are involved that have lower degrees of weldability, requiring pre heat treatment in case of repairs at very low temperature or post weld heat treatment in many cases.

For welded tubular joints, Figure 9-6, fatigue has been judged to be critical with regard to integrity of offshore structures in deep water or rough sea applications. Numerous ocean structures are predicted to experience 10^7 - 10^8 stress cycles of relatively low amplitude over their design life. However, most experimental data relevant to fatigue of welded tubular joints extend only to 10^6 cycles. Consequently, William H. Hartt undertook a research effort to develop sea water fatigue data in the high cycle regime and thereby contribute to improved design of marine structures. (Hartt, W.H., 1981).

Fatigue life of freely corroding, welded specimens is not significantly affected by microgeometry of weld metal, toe radius in particular. Corrosion fatigue cracks in steel specimens exposed to aqueous saline electrolytes are more numerous than for fatigue in air

FIGURE 9-6

PROJECTED SEQUENTIAL STEPS ON FATIGUE CRACK DEVELOPMENT

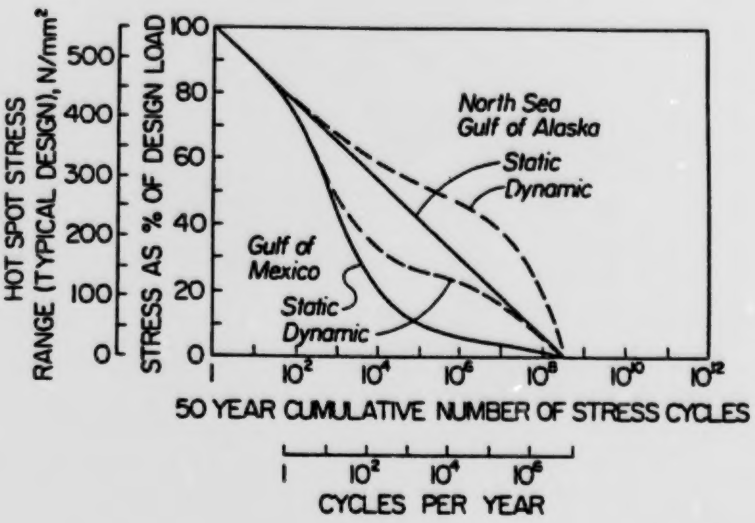

Locally Severe Geometry
Cyclic Moment
Reinforcement
(a)
Weld Toe
Plastic Deformation
(b)
Fatigue Crack
(c)
Successive Stages in Crack Development
(d)
Crack Size To Affect Significant Compliance Change (N=Ni)

Source: (Vaessen, G.H.G. et al, 1979).

and do not necessarily form at the site of maximum stress. Instead, it is more likely that severity of the profile of concentrated stress on a microscopic scale, as determined by included angle and weld height, and the influence of this upon crack growth rate is responsible. Figure 9-7 shows typical cummulative fatigue cycles as a function of stress for North Sea, Gulf of Alaska and Gulf of Mexico environments.

FIGURE 9-7

CUMMULATIVE FATIGUE CYCLES AS A FUNCTION OF STRESS RANGE FOR OFFSHORE STRUCTURES AT SEVERAL DIFFERENT EXPOSURE SITES



Source: Book on Materials Selection, Volume 1, ASM, 1977.

When evaluating the effects of weld profile/weld finishing, stress relieving and stress ratio, G.H.G. Vaesson found the following:

- The S-N curves (based on stress range) obtained for air and sea water clearly reveal a deleterious effect of the sea water on fatigue endurance. In sea water, fatigue endurance was found to be at least a factor 2 to 3 shorter than in air.

- The plate steel thickness does not influence significantly the fatigue strength in air and sea water of the 40- and 70-mm welded steel joints.
- The stress ratio has small influence on the fatigue strength (based on stress range) in air and sea water of welded steel joints loaded in bending. An increase in stress ratio from R = -1 to R = 0.1 results in some decrease in fatigue strength. The effect was found not to depend on the environment (air or sea water) and to be more pronounced for the stress relieved specimens than for the as-welded specimens.
- Grinding and plasma dressing of the weld toe increase the fatigue life in air as well as in sea water. TIG-dressing of the weld toe gives only a slight improvement, especially at long lives. A less steep toe angle (45° vs 70°) has only a slight beneficial effect.
- The test results in air are in good general agreement with existing fatigue data and seem to be described safely by the fatigue design rules. (Vaessen, G.H.G. et al, 1979).

While welding technology for shop and site fabrication in Canada is in a potentially good position to take advantage of the future increased activities in the offshore/Arctic areas, underwater welding needs a conscious effort to become competitive (Welding Institute, 1981).

Particularly underwater welding inspection lacks guidance from regulatory societies respecting procedures, documentation and qualification. The rules are fragmented and only partially available, however, and for such extremely important structural elements as node joints of steel jacket structures, no inspection guidelines are in existence. (Mittleman, J. et al, 1981).

An additional problem is lamellar tearing. It occurs at points where large diameter, heavy wall pipes intersect and are welded together. Usually caused by welding strains in the through-thickness direction, it could be controlled to some extent by fabrication and design.

Recently, attention is also being paid to the development of cleaner steels. The main emphasis here is on lowering the sulphur content: the lower the sulphur content, the more forgiving the steel becomes in fabrication and service. It is the objective to form a sulphide which is not malleable at rolling temperatures, but makes the steel more isotropic.

Available options to combat lamellar tearing are:

- specifying the use of steels resistant to lamellar tearing;
- designing the structure to avoid heavy weldments and through-thickness stresses;
- designing weld joints to involve large portions of the cross-sections of the structure members.

One special option is the forged node cans which were developed by Kawasaki Steel Corporation. Their new forging process to produce the node cans involves hollow-input making, forging, normalizing/tempering and final machining. Tests were conducted using full size models measuring 1220 mm in outside diameter, 100 mm in wall thickness and 5590 mm in length. The test results show that the new heavy wall forged pipe improved the reliability of node cans for offshore structures. (Aso, K. et al, 1980).

9.6 SPECIAL REQUIREMENTS FOR ARCTIC VESSELS

The existing rules and regulations do not specify that high tensile steel shall be used in Arctic Class vessels. However, in order to reduce the hull weight and provide additional strength against ice impact damage, the practice will undoubtedly adopt high tensile steel plating for the hulls of all of the higher classes of Arctic ships. In fact, ships of Class 4 and upward are now using H.T. steel plating and it can be expected that this practice will extend downward to Class 3. In the lower classes, the practice will probably be to continue with the use of mild steel.

The minimum rule plate thickness varies inversely with the square root of the yield strength. The basis yield strength for EH grade steel is used as 340 MPa and for C-Mn LT 60 as 355 MPa.

The plate thicknesses can be calculated in each area using a typical spacing distance between the main frames, the ASPPR Regulation formation and ASPPR Regulation pressure in each case. Plate thickness in hull areas is not defined in the regulations.

The grade of steel required for Arctic vessels can be selected for each region by using Lloyd's Regulations and current practice for ice-capable vessels.

All plating exceeding 25.4 mm is to be equivalent to Lloyd's Grade E. In the case of vessels calculated for Arctic Class 4 and higher, all steel exceeding 25.4 mm should be taken as high tensile (yield exceeding 315 MPa) and as Grade EH, except where low temperature grade is required. In general, for the thicker material, low temperature grade is required in ships subject to very low air temperature. This material can be taken as equivalent to a Lloyd's C-Mn LT 60 steel and will be more widely applied to the higher Arctic classes, which, of course, are permitted to operate in more extreme conditions.

Steel well below the waterline will not need to be low temperature grade and may be EH. For moderately low temperatures, EH grade is satisfactory especially in the thinner material, whereas low temperature steel is increasingly required as the material thickness is increased with higher Arctic classes and larger vessels.

Low temperature steel may be required for areas of plating of 30 mm thickness for a Class 4 vessel, whereas no low temperature steel below 35 mm thickness is required for Class 7 and higher vessels. This is due to the fact that all material in the ice belt exposed to low temperatures in the higher Arctic classes is in excess of 35 mm, whereas with lower Arctic classes, some of the ice-belt plating above the lightest operating waterline may be less than 35 mm. For lower Arctic classes (below Class 4) the minimum thickness of low temperature steel may extend down to 25.4 mm and thinner.

Recent studies for an Arctic Class 7 ice-breaking vessel for year-round service in the Arctic, with lower temperatures anticipated at -50^{O}F, have resulted in the selection of a low sulphur modified type Grade EH plate with columbium for the ice-belt plating and Grade E plate for the remainder of the main hull, both grades being normalized. The ice-belt plating could provide the best compromise between the notch toughness necessary and the cost of the material, heat treatment, testing and welding procedures.

Full weight saving benefits of higher tensile steels with improved notch toughness, cannot be obtained in this type of vessel where a minimum plate thickness is required against deflection of the plate due to impact with the ice.

Until new regulations are written, making the selection process easier for all concerned and ensuring a uniform set of standards throughout the Arctic world, the requirements for each vessel must be studied individually and the best compromise secured.

Some saving in steel weight and/or steel plate thickness can be anticipated as a result of the application of the new low friction coatings recently developed. For instance, U.S. ice-breakers tended to have an allowance of one quarter inch on the plating thickness for corrosion, resulting in approximately 175 tonnes of sacrificial steel for the vessels in question.

9.7 DEVELOPMENTS OF LOW TEMPERATURE STEELS

Treating of steels for improved toughness and fatigue properties using calcium shows promise for the three plate steels - A516-70, A633C and A514F. (Wilson, A.D., 1979).

Calcium treatment (CaT) is a practice that is performed in the ladle after molten steel has been tapped from the electric furnace. This treatment is used when a maximum sulphur level of 0.010% is required and can give very low sulphur levels. Calcium treatment involves adding calcium to the molten metal in the form of calcium compounds in the bottom of a ladle, or through injecting the compounds into the steel.

A516-170 is a plain C-Mn steel, A633C Lukens "Frostline", is a heat treated, microalloyed (0.05% maximum columbium), C-Mn-Cb steel and A514F is a high-strength structural alloy steel, which is used in the quenched and tempered condition.

For the steels evaluated, improvement of the tensile ductility, as monitored by the percent reduction of area, takes place primarily in the through-thickness testing orientation, and somewhat in the transverse orientation. The toughness, as measured by upper shelf determination by Charpy V-Notch, dynamic tear and J-Integral fracture toughness, is significantly improved in all testing orientations. The fatigue properties, as measured principally by fatigue crack propagation testing, are only slightly improved in A516-70, while being significantly enhanced in the higher strength A633C and A514F steels in the transverse orientation.

Many different steels have been developed for low temperature service in recent years. However, there is a need for developing an optimum steel for the range of thickness and temperatures specific to Arctic offshore structures. Not all of the steel in a platform need, of course, exhibit the maximum toughness. Furthermore, it is always advisable to pay the extra cost of tougher steel than to risk a brittle fracture and the disastrous consequences.

10. DEMAND ANALYSES FOR THICK STEEL PLATE

10.1 GENERAL

Based on the equipment requirements for each project identified in Section 7 and the equipment descriptions in Appendix A from which the thick steel plate requirements are extracted and shown in Appendix B , the thick steel plate orders for projects and years are identified in Appendix C.

For the purpose of steel plate estimates, the equipment is taken as "typical" for the particular application. By regulation, all plate of 25.4 mm and thicker must be of E Grade. Sections of structures or hulls exposed to ice in accordance with Ice Reinforcement Classes of 4 and higher are taken as Grade EH36. Application at very low Arctic temperatures requires steels of the type of Lloyds Grade C-Mn LG60. However, current construction by some designers/operators uses a modified EH36 with the sulphur content lowered to .005% for improved toughness and reduced susceptibility to lamellar tearing.

The thick steel plate requirements are forecasted for ABS Grades, E, EH36 and for low temperature steel. - Appendix C.

E Grade steel is used for piles in steel jacket structures, while EH36 is required for all cold temperature exposed special and primary structural components for application on the East Coast.

For improved structural integrity and safety regarding toughness and lamellar tearing, the requirement is increased to a modified EH36 steel. This will also permit such vessels as supply boats for use on the East Coast to travel the Arctic for periods of the year with sufficient safety margin.

Barges for installation in the High Arctic will be towed to the site once during summer time and then moored or bermed. Since they will not be exposed to severe ice loading or sea states, they can be constructed from Grade E steel.

10.2 THICK STEEL REQUIREMENTS OF ANTICIPATED OFFSHORE STRUCTURES AND ARCTIC VESSELS

For the three major exploration and anticipated production areas - East Coast, Beaufort Sea and Arctic Islands - a set of typical equipment is described in terms of thick steel requirements by grade and thickness range and is shown in Appendix B.

Data of several boats and barges are applicable to all areas.

As most of these data are based on the minimum requirements established by codes, a safety margin of up to 10% could be added to the figures given, dependent on 'designers' preference.

Furthermore, it can be expected that some designers will replace low temperature steel with the modified EH36 for the sake of economics or lack of availability.

10.3 THICK STEEL PLATE ORDERS FORECAST TO THE YEAR 2000

There will likely emerge eight major projects or project categories:

- East Coast Exploration;
- Grand Banks Oil Production;
- Scotia Shelf Gas Production;
- Beaufort Development by Dome;
- Beaufort Development by Esso/Gulf;
- Arctic Islands - Arctic Pilot Project;
- Arctic Islands - King Christian;
- Arctic Mining Projects.

Each project needs a distinct set of equipment.

Steel orders placed for each major project two years before delivery (average assumption) are shown by grade and thickness in Table 10-1.

Order forecasts per year are shown by steel grade and thickness range in Table 10-2.

TABLE 10-1

THICK STEEL ORDERS BY PROJECT
(TONNES)

	STEEL GRADE						TOTAL TONNAGE PER YEAR
	'E'		'EH 36'		LOW TEMPERATURE		
PROJECT	25-37mm	38mm+	25-37mm	38mm+	25-37mm	38mm+	
EAST COAST EXPLORATION	500	500	10750	2000			13,750
GRAND BANKS OIL PRODUCTION	6200	1200	47520	26360			81,280
SCOTIA SHELF GAS PRODUCTION	1700	1860	4800	940			9,300
BEAUFORT SEA DOME	12650	6200	39710	11310	25040	46305	141,215
BEAUFORT SEA ESSO/GULF	4000	2700	16420	2530	8250	16130	50,030
ARCTIC ISLANDS (APP)	850	800	6190	1130	4620	7250	20,840
ARCTIC ISLANDS KING CHRISTIAN	1300	1300	14680	3260	12500	21140	54,180
ARCTIC MINING PROJECTS	500		3350	1300	1550	3700	10,400
TOTALS:-	27700	14560	143420	48830	51960	94525	380,995

TABLE 10-2

DISTRIBUTION OF THICK STEEL ORDERS BY YEAR, GRADE AND THICKNESS

(TONNES)

	STEEL GRADE						TOTAL TONNAGE PER YEAR
	'E'		'EH 36'		LOW TEMPERATURE		
YEAR	25-37mm	38mm+	25-37mm	38mm+	25-37mm	38mm+	
1982	700	100	2940	1530	1250	1570	8090
1983	780	600	4710	740	920	675	8425
1984	1400	700	11770	1930	1790	1730	19320
1985	2450	1700	15980	9240	5300	10700	45370
1986	3200	1400	10660	3530	5340	10730	34860
1987	930	500	3910	810	2760	4125	13035
1988	1830	1400	7970	1240	3580	4575	20595
1989	3130	1100	23500	9550	3460	5325	46065
1990	2250	1600	7720	2200	7070	14680	35520
1991	200	200	3420	500	3060	3400	10780
1992	2150	800	13530	7940	1770	3980	30170
1993	2000	700	9690	3540	1500	3900	21330
1994	1650	800	8380	1730	5220	10250	28030
1995	1600	1360	8340	1940	5300	10700	29240
1996	350	300	2020		270	80	3020
1997	1380	200	5270	1210	370	305	8735
1998	1700	1100	3610	1200	3000	7800	18410

11. CANADIAN SUPPLY CAPABILITY

11.1 STEELMAKING

Between the two major Canadian steelmakers an annual capacity of about 1.5 million tonnes can be produced, depending on type of product, steel grade and product dimensions. Both companies produce typical ship steels - ABS Grades A,B,D,E and the high strength steel EH36. Only one has the capability to normalize steel plates.

The limitations of the Canadian steel mills are to 100 mm thickness and 3.2 m and 3.8 m of width, respectively. Dome Petroleum, as the future anticipated major Canadian ship steel purchaser, would have preferred 4 m width, but has as a concession to the Canadian steelmakers, reduced its requirements to 3.2 m. The Japanese capability is 5 m wide plates. Greater plate width improves the economics of fabrication by reduced fit-up welding and inspection requirements. For these reasons, it should be interesting to observe in the future to what extent Dome will be able to accept the cost penalties when building the large 200,000 tonne ice-breaking tankers.

It is anticipated, given sufficient confidence in market forecasts and lead time by Canadian steel plate purchasers, that the steelmakers will be willing and able to produce the majority of the steels required, even EH36 modified. Producing these in quantities that substantially exceed current capacity, in addition to the traditional product lines, is clearly a matter of confidence which the steel purchasers would need to in-still in the steel industry for several years to come. Of course, the current investment climate is not conducive to increasing the Canadian steelmaking capabilities. The Canadian shipyards require a greater demonstration of committment to actual projects before gearing themselves up to the anticipated large demand in vessel fabrication.

The quality requirements for the ship steels, for example, V-Notch toughness of 47 joules at $-40^{\circ}C$, 50-60% minimum reduction of area in through-thickness elongation tests, can currently be met by Canadian steelmakers. While these capabilities are insufficient for very low temperature Arctic application, they could likely be improved given sufficient market demand.

At this time, the international competition is overwhelming. Japanese manufacturers delivery ship steels of various grades to the Canadian West Coast at about $100 per tonne lower price (about 12%) than Canadian prices. A significant justification for designers to specify Japanese produced steels relates to a Japanese practice of substantially exceeding steel chemistry specifications, particularly sulphur content.

11.2 RIG AND VESSEL FABRICATION

After completing its shipbuilding market survey 1982 to 1991, the Canadian Shipbuilding and Ship Repairing Association announced that its members will be able to build the forecasted 400 new vessels and floating equipment of a total estimated cost (1981 dollars) of over $33 billion, with the exception of the large

Arctic LNG carriers and tankers. This healthy confidence should help to spur many of the antiquated Canadian shipyards to upgrade their plants and technical skills.

Yet, the record of the Canadian shipbuilding industry is remarkable, for it has produced several technologically innovative and successful ice-breakers and other Arctic vessels, as well as several modern drill rig designs. It is to be noted though, that these products come from a small number of prudently and aggressively managed yards, whose marketing concepts and technical skills have been adapted to modern shipbuilding industry requirements.

There are about 25 shipyards and ship repair firms in Canada, some well located in such major harbour and industrial areas as Vancouver/New Westminster, Quebec City, St. John, Halifax and St. John's. Only a few of these yards have an annual steel fabrication capability of 25,000 tonnes, being severely limited to the small and simple ships, e.g., fish trawlers and cargo ships.

While currently, a good level of success is demonstrated by the order placements in Canadian yards, it is critical that the resulting products are of high quality. Canadian yards are producing, at this time, several jack-up rigs, one semi-submersible drilling rig, one Class 4 Ice-breaker/supply ship and several ice-reinforced supply ships. The "flagship" of technology, Dome's Class 4 Ice-breaker "Kigoriak" was constructed in Canada in 1978.

For the future, the prospect of the industry to meet Canadian shipbuilding demands looks good. The large number of support vessels required for the operations on the East Coast and in the Arctic will fill the order books of most of the yards; subcontracts for modules of ships or offshore structures from the large Canadian or international yards will boost the revenue of those firms who continue updating their marketing approach, technological skills and degree of automation to remain competitive worldwide.

Most of the international competitors are supported financially for export contracts by their governments. In addition, many are nationalized shipyards which keep their many thousands of employees busy at cost or even below cost rather than putting them on unemployment payments.

In the case of the Japanese with their proven record including committment to quality of workmanship and product, the highest specification steels at low prices and a labour force that is more productive than the Canadian by a margin of 30-50%, their shipbuilding industry can hardly be outpriced by Canadians under current fiscal incentive regulations. It will likely require though, a combination of innovative marketing techniques, supported by strong in-house engineering capability and a demonstrated committment to quality of workmanship and product and an increased after-sales service, to attract the purchase orders by Canadian vessel operators.

The Canadian shipbuilding industry is heavily impeded in its ability to compete by the financial implications of building and operating ships in Canada:

- reduction of the 20% shipbuilding subsidy to 9% in July, 1980;
- no customs duty levied on foreign ships imported into Canada;
- heavy duty and tax levied on foreign equipment to furnish Canadian ships.

To alleviate the danger of being priced out of the market and to become internationally competitive and participate in the new-build market, a financing scheme in Canada is required. It should contain a well-balanced combination of an increased capital cost allowance, a loan guarantee/ insurance program, a strong intermediate term, low interest rate during construction and a clearly defined beneficial "Buy Canadian" policy. This package would permit Canadian shipbuilders to close the gap with foreign competitors cost wise. This, combined with innovative marketing techniques and a strong demonstration of committment to quality of workmanship, would yield an increasing ratio of Canadian new-build orders to Canadian shipyards.

The benefits then derived would include an increased balance of payments, reduced unemployment and increased input into regional industrial and socio-economic developments.

12. SUGGESTIONS FOR RESEARCH PROGRAMS

In two major technological areas, opportunities exist for Canada's relevant industries to improve their degree of competition:

- properties of cold temperature steels; and,
- modern shipyard operation.

As the greatest deficiency in the material properties field was found to be the lack of knowledge of requirements under very cold temperatures, a data bank should be established. It should provide detailed answers on design and engineering properties and be publicly accessible. For example, such details as minimum V-Notch toughness, or optimum combinations of steel/type of design/post weld heat treatment are needed for use at low temperatures. The information should be developed for plate thickness up to 25 mm and greater, possibly up to 50 mm.

Following the generation of this data, steel quality improvements or adaptations to achieve the most economical combination of material properties for specific applications should be instituted. Subsequently, tests should be carred out to establish formability and weldability, fatigue and corrosion resistance, as well as through-thickness ductility. For particular structures, tests on realistic tubular node and other connections should be conducted to determine the flaw size effect on toughness. It is known that PWHT can effectively compensate the loss of toughness due to increase in thickness, but this needs verification for the steels under consideration.

In the area of shipyard operation, it is suggested that a nationwide study be carried out to identify the optimum operation including:

i) flow of construction material through the plant;
ii) modern fabrication techniques; and,
iii) cost effective use of modern equipment.

This evaluation should then be continued for individual yards with the goal of recommending improvements that are specific to the company's spectrum of business.

A substantial increase in the cost efficiency of operations could be achieved by upgrading the skills of the yard personnel. This could be done by training programs which are geared to the different personnel levels and considering the company's line of activities.

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APPENDIX A

SYSTEM DESCRIPTIONS

APPENDIX A

A.0 SYSTEM DESCRIPTIONS

A.1 DRILL RIGS - JACK-UP

Only a few jack-up rigs are fabricated in Canada and then, under licence. Typically, they employ a triangular shaped hull, supported by open trussed legs at each corner and a cantilever platform bracket. The main hull is usually constructed of mild steel employing comparatively thin plating 7mm to 12mm thick. Plate thicknesses of 25 mm and up are minimal, and, for the purpose of this forecast, negligible.

A.2 DRILL RIGS/VESSELS - FLOATING

The new generation of semi-submersible drilling rigs considered to be suitable for work on the East Coast in the medium water depth range of 500 m to 1500 m and operating deck loads of between 3500 and 4500 tonnes, include the Aker H-3.2, the Gotaverken Arendal GVA-4000, the Stena Challenger of Stena Line, the Zapata SS-4000, the Dyvi Delta, an Ocean Ranger type design, the Ben Ocean Ranger by the British National Oil Corporation and Ben Odeco (another Ocean Ranger type modification) and possibly, the semi-submersible rig concept under development by C.G. Doris, featuring hulls made from concrete.

Following are descriptions of two likely typical designs.

The Aker H-3.2 may turn out to be a standard semi-submersible drilling vessel for the 1980's and early 1990's in such areas as the Grand Banks, while a design similar to the currently developing BS-8000-DP by V.O. Offshore (British Shipbuilders Group), could be used in the 1990's as the standard vehicle for exploration in the deeper areas of the Grand Banks and in Labrador. Aker's H-3.2 is a further development of the well known H-3 semi-submersible. Figure A-1 shows an artists conception of the H-3.2.

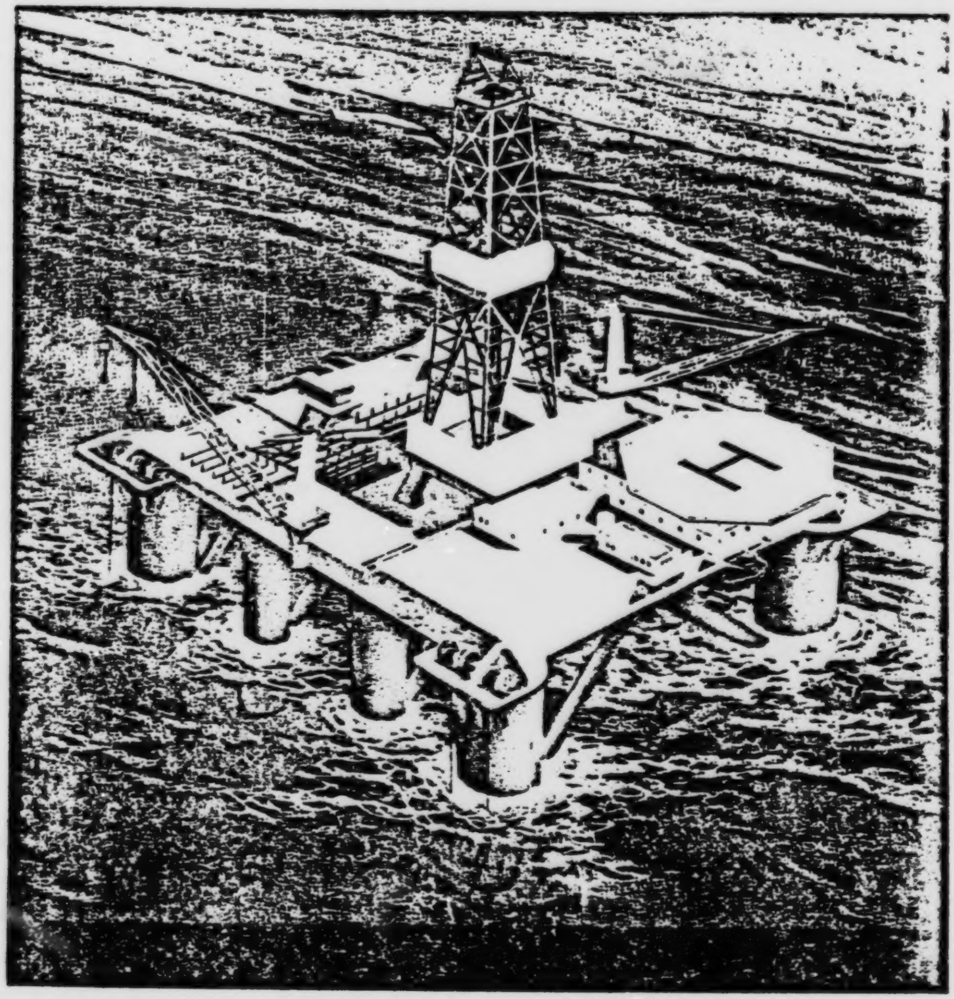
Planned for application in extreme environmental conditions, the H-3.2 features two single pontoons with each supporting four vertical caissons. Its overall length is 92.5 m, its breadth 67.20 m, with a displacement of 24,000 tonnes. Figure A-2 lists technical data. The first H-3.2 semi-submersible is now being built in the Company's Verdal, Sweden yard.

The 8,000 tonne capacity semi-submersible BS-8000-DP of V.O. Offshore is a six-leg supported dual hull structure which is planned to be outfitted to a class of higher standard of sophistication and convenience for work in the most extreme environments, see Figure A-3. Its design and operational characteristics include 8250 m holes in 1650 m of water, 8 mooring lines for use in water of up to 450 m depths and 8 azimuthing variable pitch thrusters for greater water depths. To reduce cost and construction time, the structure of the hull and the vertical columns are composed of flat panel assemblies; the columns are 12-faceted. In model tests, survival in 36.5 m waves was indicated.

This type of design could well indicate the structures of the distant future, when the need will arise for Canadian explorers to move into greater water depths and extend the "weather window" to substantially more than one third of the year.

FIGURE A-1

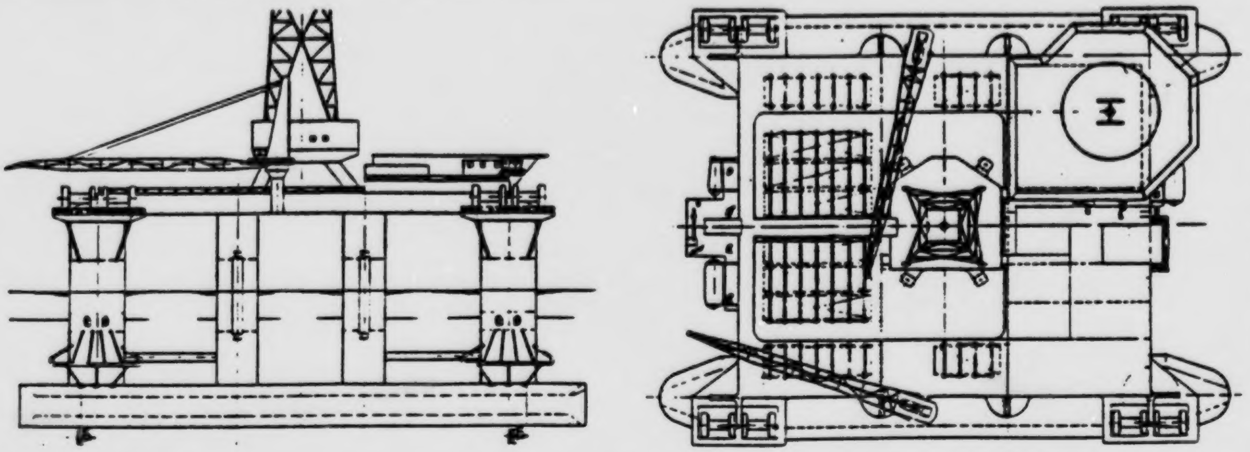
ARTISTS CONCEPTION OF THE AKER H-3.2



AKER H-3.2 GENERAL DESCRIPTION

FIGURE A-2

GENERAL ARRANGEMENT



Principal particulars

Length over all	92.50 m	303 ft
Breadth moulded	67.20 m	221 ft
Length upper hull	67.50 m	221 ft
Breadth upper hull	54.00 m	177 ft
Elevation lower deck	34.50 m	113 ft
Draft operating	22.00 m	72 ft
Displacement (chain)	24025 tonnes	
Displacement (wire)	24170 tonnes	

Supply capacities

	Tonnes
Bulk and mud cement	1000
Sack materials	350
Pipe racks	1200
Liquid mud	530
Fuel oil	2130
Drill water	2000

Payloads (with full column bulk)

	Tonnes	
	Chain	Wire
Operating deck load	3600	3900
Storm deck load	3000	3400
Transit deck load	3000	2900
Transit payload d=6.9 m	2700	3800
d=10.0 m	4400	5600

DRILLING

Drilling depth = 7600 m (25000 ft).

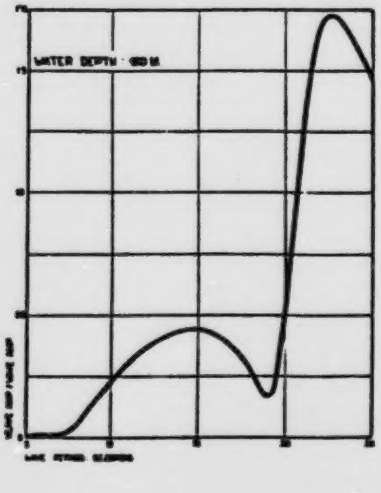
Derrick
48.8 m (160 ft) high derrick. Designed for 455 tonnes (one mill. lbs) 5.5 m (18 ft) stroke drill string compensator.

Drawworks
Rated for 7600 m (25000 ft) of 5 in. drill pipe. Equipped with three 588 kW (800 hp) motor.

Rotary table
49.5 in. rotary with one 588 kW (800 hp) motor.

Mud pumps
Two triplex mud pumps, each with two 588 kW (800 hp) motors.

HEAVE RESPONSE



MISCELLANEOUS EQUIPMENT

Deck cranes
Two 40 tonnes (88185 lbs) deck cranes with 36.6 m (120 ft) long jib.

Power plant
Four diesel generating sets with a total output of 8500 kVA/600 V AC/60 Hz.
Transformers are installed for conversion to 600/440/220 Volts.
Thyristor plant for AC/DC conversion.

Anchors and mooring

- Eight wire winches or eight chain cable windlasses with mechanical and hydraulic braking.
- Eight 15 tonnes anchors.
- Eight 76 mm (3 in) dia. chain cables of continuous length 1700 m (5577 ft) or eight 83 mm (3¼ in) dia wires each 3300 (10826 ft) long.
- 12 point mooring can be accommodated if required. It is recommended for satisfying proposed new regulations for drilling in shallow water i.e. 70–140 m.

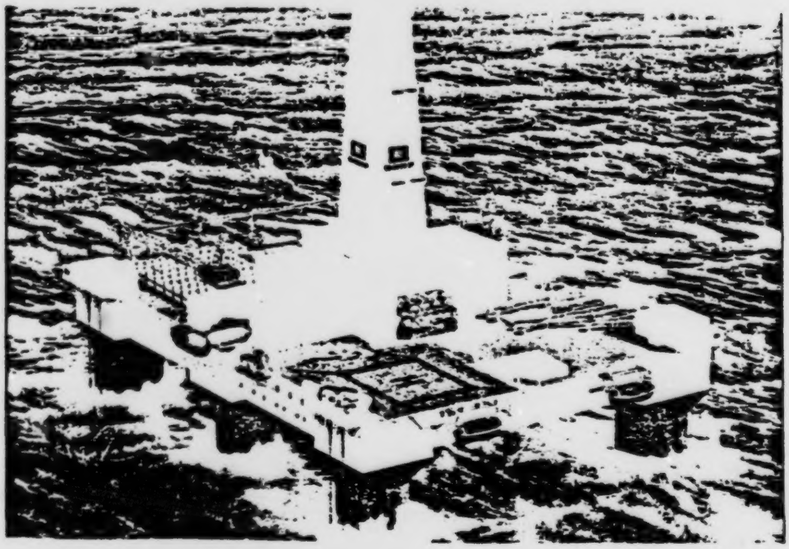
Accommodation
Air conditioned quarters for 90 men arranged on three decks, in 1 and 2 berth cabins.

Heliport
Designed for Sikorsky S-61 helicopter.

Options
Alternative equipment and accommodation can be arranged according to clients' requirements. The concept can readily be adapted to applications such as construction support, accommodation or multi-purpose service vessel.

FIGURE A-3

THE V.O. OFFSHORE BS-8000-DP



The costs of drilling rigs have escalated over the years, well in line with other industries. In 1971, an 80 m depth jack-up rig cost $6 million (U.S.), in 1975 $13 million (U.S.) and in 1981, about $30 million (U.S.). A jack-up rig with a 100 m water depth capability cost about $35 million (U.S.) in 1981.

A medium sized semi-submersible of the Aker H-3 design had a delivery price of about $60 million (U.S.) in 1981, compared with $30 million (U.S.) in 1975 and $12 million (U.S.) in 1971. A heavy weather semi-submersible larger than the Aker H-3 having a design for moderate ice and North Sea type weather conditions cost about $80 million (U.S.) in 1981. (Rig Construction).

While these prices are in U.S. dollars, the purchase price of the Breadford Dolphin (now named BowDrill I) was $133 million (Can). This is an Aker H-3 semi-submersible of mid-1970's vintage.

Figure A-4 shows the cost escalation of mobile rigs extracted from the above reference.

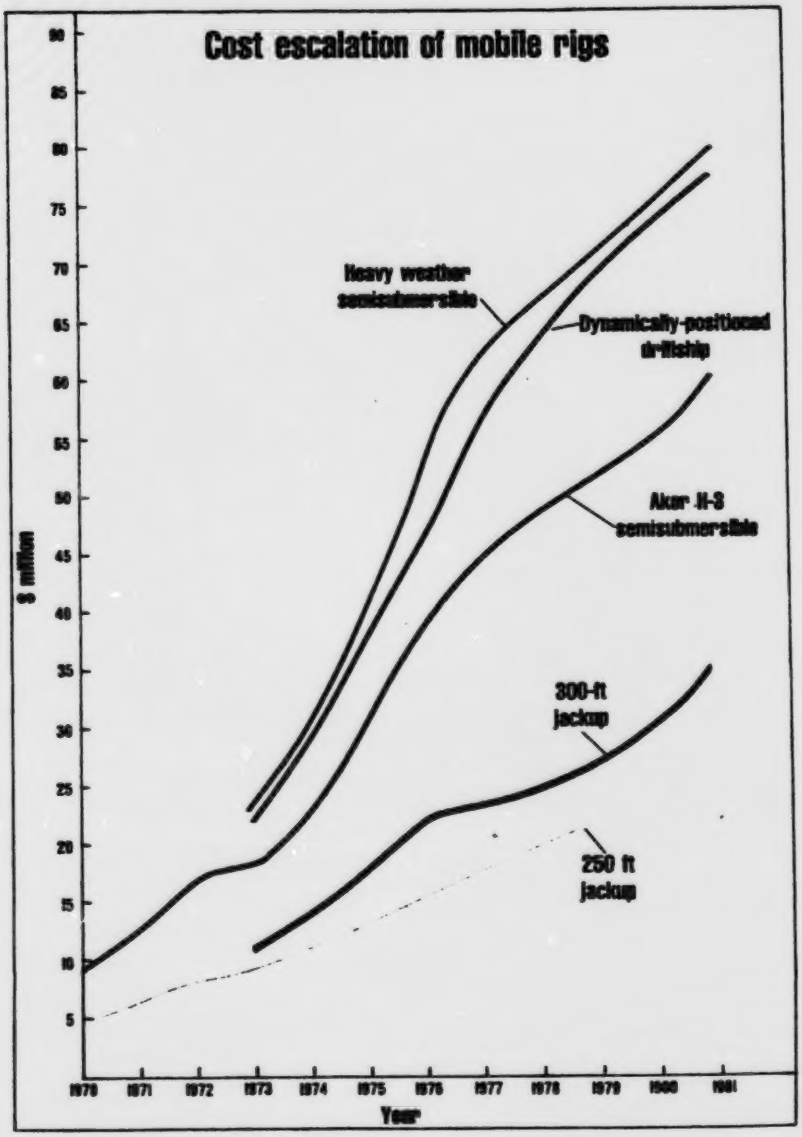
The offshore platform market is likely going to see an oversupply situation for the next two years. Wood, MacKenzie & Company of London expects the cancellation of several mobile rigs under construction, while Ronald C. Lassiter, President of Zapata Corporation, sees only a levelling off in the market for moderate environment jack-ups.

A.3 PRODUCTION PLATFORMS - GRAVITY - STEEL

The experience in developing the North Sea oil and gas reserves during the last fifteen years is relevant to an extent to the future Canadian East Coast activities. A variety of extremely large and high capacity crude oil platforms of steel and of concrete are operating in the environmentally extremely harsh area of the northern North Sea which is, except for drifting icebergs and ice-pack, comparable to the Canadian East Coast situation. Following therefore is a brief overview of the North Sea experience.

Typically for North Sea platforms, design, construction and installation required a period of three to four years, requiring to withstand the hundred year survival wave height of 30.5 m including resistance to damage caused by sea water oxidation and impact. Two basic types of platforms are used in the North Sea - the steel jacket platform, attached to the sea bed by

FIGURE A-4



Source: Offshore Magazine, 1982-1.

piling, and the concrete gravity platform. In addition, floating production platforms based on semi-submersibles have been used.

Table A-1 represents the steel platforms in use or scheduled for installation by 1984 in the U.K. sector, while Table A-2 provides similar information for concrete platforms.

Based on the experience of over twenty steel platforms, the relationship of total steel weight to depth of water is almost linear - Figure A-5.

While this correlation exists for steel platforms, it could not be found in the case of concrete gravity platforms. There, a wide spread of concrete weight to production capacity exists, possibly because of the wide variety of users concrete platforms have been designed for, e.g., the greater variety of design concepts (Condeep versus outer and inner wall used for Ninian). The design specifications for concrete platforms are limited, but allow a wide margin of custom design.

In a comparison conducted by J. Kenneth Klitz, it was found that the requirement for direct resources to construct a steel versus a concrete platform is nearly equal. Steel requirements for the concrete platform, in terms of tonnage, is nearly as high as for the steel platform alone, but of considerably lower steel quality.

While there is no evidence to prefer one construction material over the other, most of the concrete platforms have included an important additional systems element, the intermediate storage of the produced oil

TABLE A-1

Steel platforms in use or scheduled for installation by 1984 in the U.K. sector of the North Sea.

Platform	Weights (tonnes) of				Water depth (m)	Total number of wells[a]	Peak production rate of crude oil[b] (× 10⁶ tonnes/year)	Expected lifetime production[c] (× 10⁶ tonnes)	Storage capacity (barrels)
	Structural steel	Deck	Modules and equipment	Piles					
Argyll[d]	4,500	–[e]	2,300	–	79	8	1.1	4.5	–
Auk	3,360	450	5,000	1,960	84	12	2.3	8.0	–
Beatrice									
Drilling	4,600	–[f]	3,538	4,500	45	32	–	–	–
Production	4,300	–[f]	4,973	4,500	45	–	3.1	16.0	–
Jack-up (Zapata Nordic)	8,200	–[f]	–[e]	–	45	12	0.8	5.0	–
Brae	16,000	–[f]	31,000	11,600	103	46	4.9	36.0	–
Brent A	14,000	1,800	9,580	7,200	140	28	4.86	41.0	–
Buchan Semi-submersible (Drillmaster)	18,083	–[f]	3,000	–	120	11	2.2	6.8	12,000
Claymore	9,286	1,000	12,286	3,135	110	36	4.5	55.0	–
Forties									
FA (Graythorp I)	15,436	–[f]	10,551	6,428	106	27	6.2	60.0	–
FB (Graythorp II)	18,253	–[f]	10,551	7,417	122	26	6.2	60.0	–
FC (Highlands One)	18,398	–[f]	10,551	7,417	127	27	6.2	60.0	–
FD (Highlands Two)	16,892	–[f]	10,551	7,417	122	26	6.2	60.0	–
Fulmar									
Fulmar Main Jacket (A)	12,500	4,900	22,500	5,000	82	36	8.6	70.0	–
Fulmar Wellhead (B)	1,570	250	–	1,000	82	6	–	–	–
Hutton[j]	38,468[g]	–[f]	16,530	–	147	32	5.7	24.0–34.0	–
Magnus	40,700[h]	–[f]	30,800	12,240	187	27	5.9	60.0	–
Maureen	40,000	–[f]	16,200	–	98	19	4.0	21.0	650,000
Montrose	6,500	1,600	4,486	2,300	90	24	1.4	12.0	–
Murchison	18,900	5,000	24,000	8,544	156	30	7.2[i]	51.0[i]	–
Ninian									
Northern	17,000	–[f]	9,000	6,000	140	24	3.93	34.4	–
Southern	20,000	–[f]	17,497	8,000	140	42	6.88	60.3	–
North Cormorant	21,300	1,800	44,467	6,100	160	40	7.3	55.0	–
North West Hutton	16,000	1,372	25,700	6,500	144	40	5.1	37.5	–
Piper	12,972	1,089	5,715	8,016	122	36	12.6	88.0	–
Tartan A	17,000	1,400	18,600	8,400	142	33	4.0	27.0	–
Thistle	31,650	–[f]	25,930	13,000	162	70	8.7	69.0	70,000

[a] Total possible number of production, subsea, and water- and gas-injection wells; in other words, the total number of well conductors or well slots plus the subsea wells.

[b] Values given are based on the maximum specified capability of each platform, and assume 365 days/year of peak production. Generally, these data were obtained direct from the operating companies.

[c] Based on operators' estimates published (June 1980) by the U.K. Department of Energy, and assuming that the platform will last for the production lifetime of the field.

[d] Semi-submersible rig employed as a production platform.

[e] Included in the weight of structural steel.

[f] These decks are integral parts of the modules and/or the platforms.

[g] Including vessel, risers, mooring lines, and anchors.

[h] Self-floating structure.

[i] Including production and reserve data for the part of the Murchison field which lies in the Norwegian sector.

[j] Floating tension-leg platform.

TABLE A-2

Concrete platforms in use in the U.K. sector of the North Sea.

Platform	Weights (tonnes) of						Water depth (m)	Total number of wells[b]	Peak production of crude oil ($\times 10^6$ t/yr)[c]	Expected lifetime production ($\times 10^6$ t)[d]	Storage capacity (barrels)
	Structural steel	Reinforcing steel	Prestressed steel	Concrete[a]	Deck	Modules and equipment					
Beryl A	630	9,000	3,000	192,000	6,962	20,000	117	44	5.00	66.0	900,000
Brent											
B	900	10,000	1,600	153,770	3,100	11,590	140	38	7.79	66.0	1,100,000
C	–	14,000	1,100	267,900	6,400	13,280	140	40	7.30	61.0	550,000
D	630	14,000	1,400	158,970	3,200	11,200	140	48	7.30	61.0	1,100,000
Dunlin A	1,450	9,500	3,000	211,050	3,800	11,300	151	48	5.90	41.0	800,000
Ninian Central	10,000	30,000	–	356,000	15,000	45,000	140	42	6.88	60.3	–
South Cormorant A	–	13,500	1,000	275,500	4,500	13,000	149	36	3.00	12.0	1,000,000

[a] Excluding any grouting materials required for platform installation.

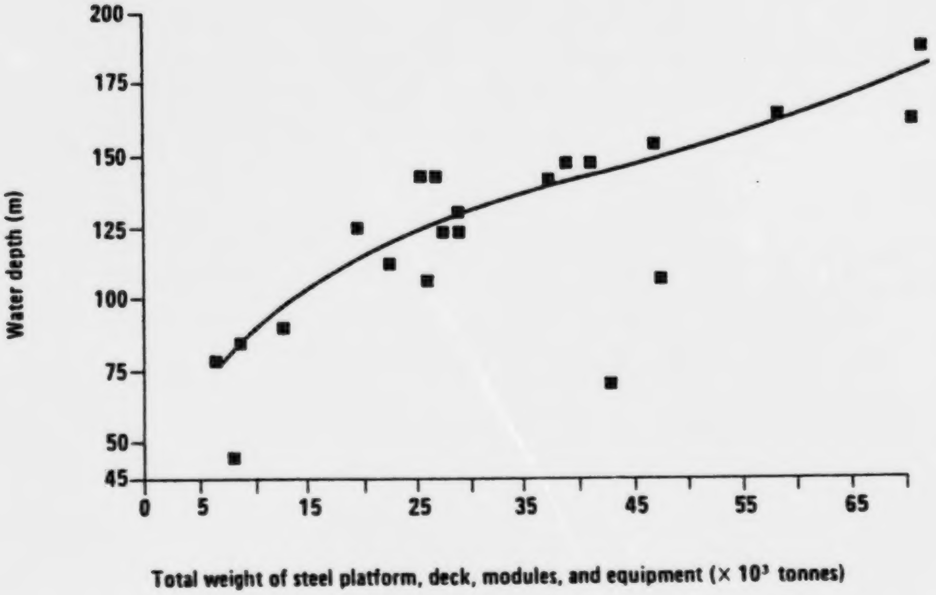
[b] Total possible number of production, subsea, and water- and gas-injection wells; in other words, the total number of well conductors or well slots plus the subsea wells.

[c] In million tonnes/year; values given are based on the maximum specified capability of each platform, and assume 365 days/year of peak production. Generally, these data were obtained direct from the operating companies.

[d] In million tonnes; based on operators' estimates published (June 1980) by the U.K. Department of Energy, and assuming that the platform will last for the production lifetime of the field.

FIGURE A-5

RELATIONSHIP BETWEEN TOTAL WEIGHT OF STEEL PLATFORM AND WATER DEPTH



Source:

before transporting to market, if a pipeline is not available and shipping is carried out via tankers. This factor may be significant in the Canadian East Coast oilfields where the pipeline option is likely not feasible.

A typical North Sea Platform in a 150 m water depth is estimated to cost $1.5 billion (U.S. 1981 dollars) Figure A-6.

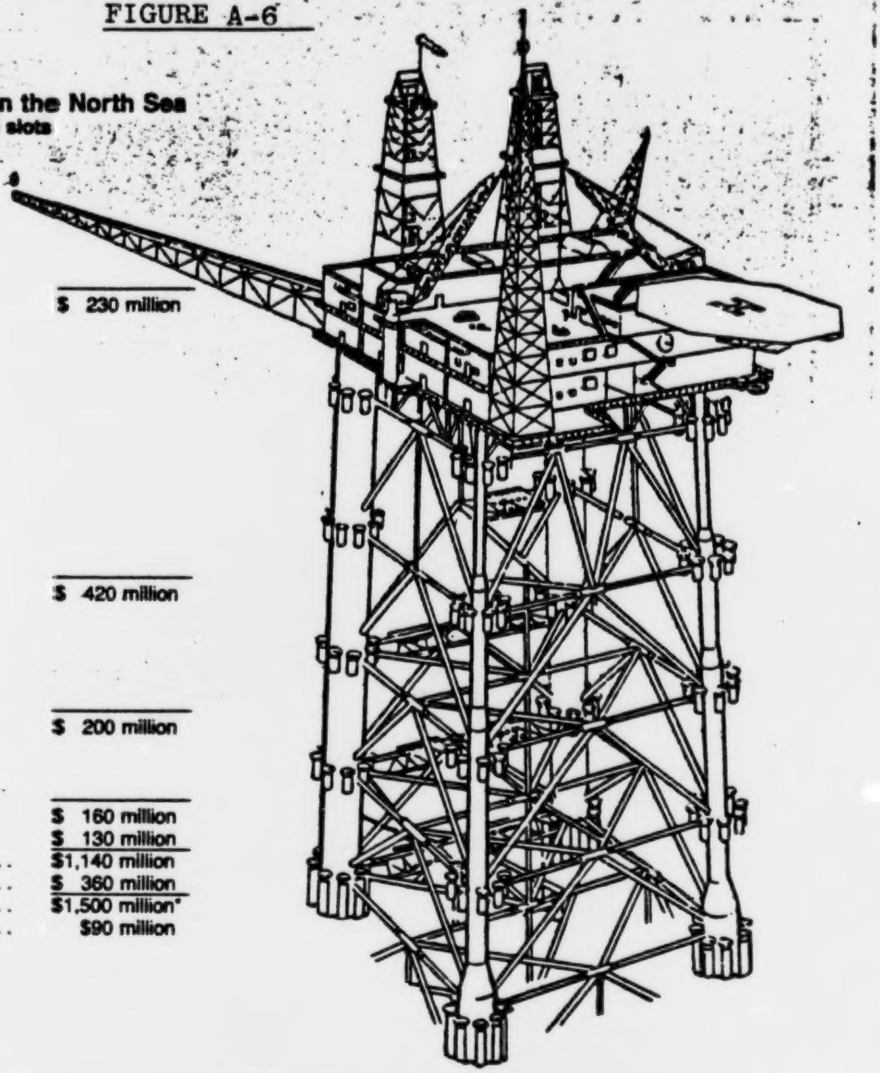
Following are examples of recent international installations as they might apply to Canadian conditions.

FIGURE A-6

Cost of
Drilling/production platform in the North Sea
500-ft water depths/36 slots

Jacket Structure	
Materials-steel	
Piles/skirt piles	
Legs	
Buoyancy tanks	
Risers	
All other steel	
	$ 230 million
Topside Facilities	
Decks	
Accommodation modules	
Processing equipment	
Compression equipment	
Instrumentation	
Helideck	
Firefighting/lifesaving equipment	
Pumps	
Water systems	
Cathodic protection	
Heat exchangers, etc.	
	$ 420 million
Installation Costs	
Load-out	
Tow-out	
Placement	
Hook-up, etc.	
	$ 200 million
Oil Disposal Facilities	
SPM/Tanker or	
Tie-in pipe line	
	$ 160 million
Miscellaneous	$ 130 million
Total	$1,140 million
Development drilling	$ 360 million
Total project cost	$1,500 million*
Annual operating costs of this platform	$90 million

*Figured in 1981 dollars. Courtesy Wood McKenzie.



Source: Ocean Industry, October, 1981 pp88.

Texaco U.S.A., is planning to install this year, its large natural gas production platform called Habitat in 109 m of water in the Santa Barbara Channel, in California. The structure features eight legs and 24 slots and is planned to produce initially 428 x 10^3 m^3/d of natural gas followed by a peak production of

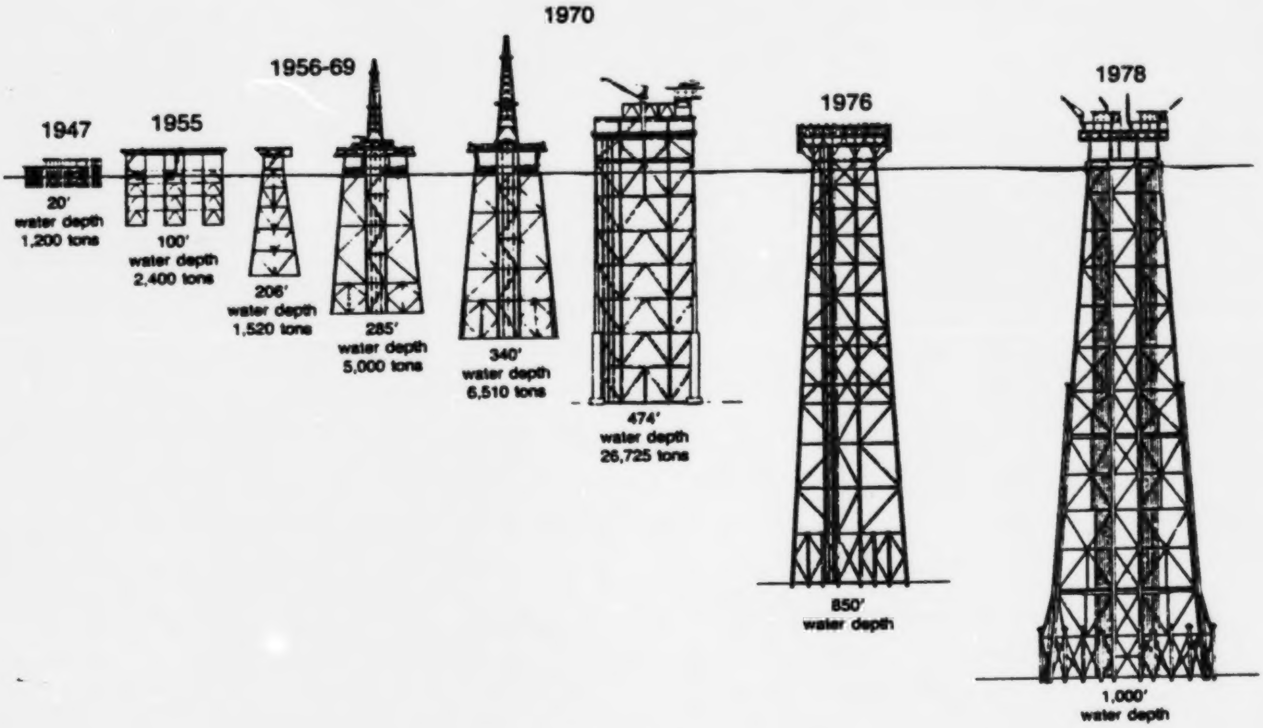
1.7×10^6 m^3/d in late 1983. The structure is expected to cost close to $80 million (U.S.). It is designed to withstand 38 m/s winds and 15 m waves. Constructed at Nippon Steel's Wakamatsu, Japan yard, Habitat's platform jacket will be barge launched.

The evolution of production platforms to greater depths is illustrated, in Figure A-7 (Lee, G.C., 1980), as a jump from 6 m water depths and 1200 tonnes structure weight in 1947 to 330 m water depth in 1978.

To a large extent, the ability to go to greater depths with pile-attached steel platforms depends on the type of installation of the jacket by either launching from a barge or self floating.

FIGURE A-7

THE EVOLUTION OF PRODUCTION PLATFORMS TO GREATER DEPTHS


1947
20' water depth 1,200 tons
1955
100' water depth 2,400 tons
1956-69
206' water depth 1,520 tons
285' water depth 5,000 tons
340' water depth 6,510 tons
1970
474' water depth 26,725 tons
1976
850' water depth
1978
1,000' water depth

Some of the largest production platforms recently installed include the 26,000 tonne, 312 m high Cerveza platform in 306 m water depth, located 175 km south-east of Galveston, Texas in the Gulf of Mexico.

This jacket was fabricated as a one-piece, requiring 2100 structural jacket members and about 2100 welded joints. 40% of the jackets main frame members were sized on load out and launch requirements.

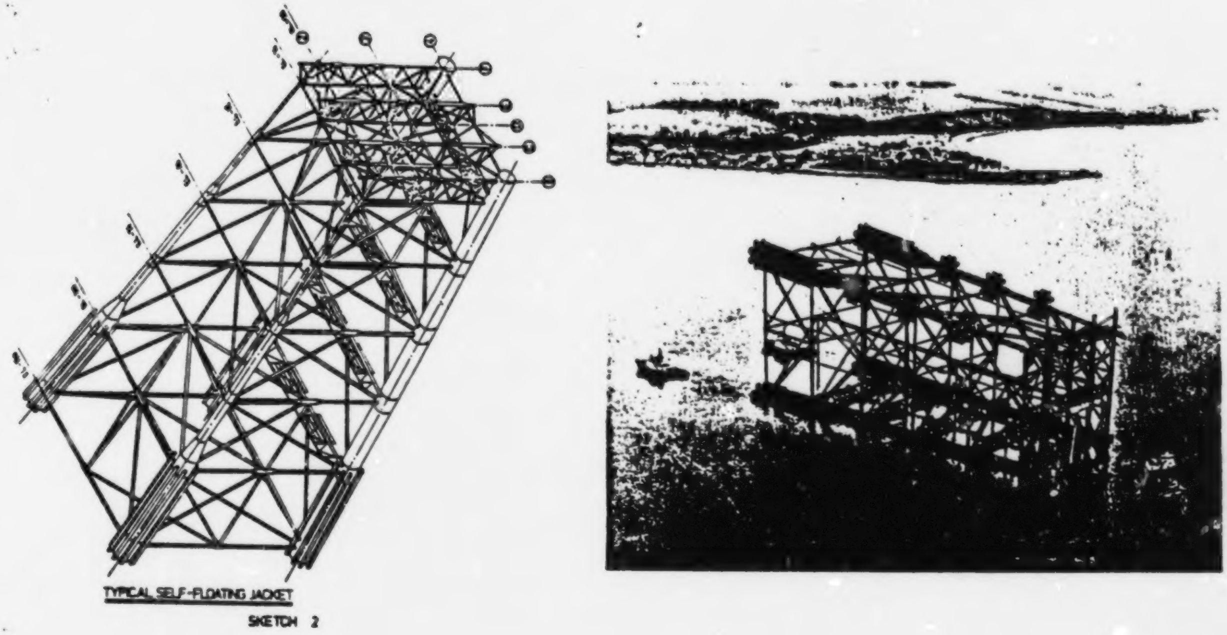
While the Cerveza structure is currently the largest single piece jacket, the 44,000 tonne Magnus platform is the world's heaviest single piece structure. Currently in its final stage of construction at Highlands Fabricators Nigg Bay Yard in Scotland, the platform is being assembled on its side for float-out in the horizontal position. It features 16 major leg nodes, each weighing from 500 to 1200 tonnes, and more than 20 nodes of 50 to 100 tonnes each.

The platform will be installed in 200 m water, 200 km northeast of Shetland, and will therefore be the most northerly completed platform when installed. By 1983, it is expected to produce an average of 19,000 m^3 of oil per day.

Analysis of the requirements of steel plates of thicknesses of 25 mm and up shows that the highest loaded elements in these jackets, the leg/bracing/deck joints or K-Joints, differ from earlier designs only in sophistication, and very little in thickness requirements and total weight. The exception is cast or forged nodes which are not yet widely used, but which could become the most common node material/fabrication method in the mid term.

Typical of self-floating jackets, the Ninian Field platform, Figure A-8, was designed on a minimum member approach, resulting in heavy wall thicknesses and complex, heavy internally-stiffened joints. The minor leg joints at 110 mm wall thickness have joint weights of 80 tonnes, while flotation leg joints of about 9 m in diameter and 40 mm wall thickness weigh up to 300 tonnes.

FIGURE A-8
THE NINIAN FIELD SOUTHERN PLATFORM



Source: Walker, R.C. and Winton, J.H. 1979.

Typical barge-launched structures necessarily incorporate two parallel legs along one face of the structure to support the weight of the whole structure during the final stages of erection and, more significantly, to absorb the high local loading stresses during launching at sea. Two different designs are common - a minimum member approach, and therefore thicker wall sections, or multi-lightweight member design featuring maximum leg wall thicknesses of 50 mm and typical brace sizes of 800 x 30 mm wall thickness increased to between 35 and 40 mm at their fixed ends. The overall structural weight for these two different designs is quite similar, but potential for cost savings exist depending on skill and efficiency of jacket fabricators.

The materials used in the more recent installations in the North Sea included special structural steel BS-4360-50D (modified) type 2 normalized, which is extensively used for node barrel fabrication and on main girders where major design stresses are applied through the thickness of material and coupled with high stress concentrations caused by the welding of complex stub branch configurations. It was found though, as part of the North Sea experience, that the improved through thickness properties of the modified 50D for unique tubular fabrication could be achieved only through employing complex welding/fabrication sequences to reduce the problem of lamellar tearing in the steel below the weld area. Additionally, it was found necessary to reduce the sulphur level in the steel to below .01%. With most present-day 50D modified steels, the level is below .005%.

A further improvement of the through-thickness toughness was achieved (Walker, R.C. and Winton, J.H., 1979) by micro-alloying additions such as niobium, improving the strength by precipitation hardening and by improved grain refining. These measures resulted in the high through-thickness elongation of at least 28%, combined with a very high fracture toughness (by Charpy V-Notch Test) in excess of 12 joules at -55°C.

As the primary structural steel, BS-4360-50D normalized type 1 differs from type 2 mainly by a higher level of impurities like sulphides and silicates and resulting lower stress toughness and ductility values. This grade still shows a high fracture toughness of about 72 joules at -40°C, and is used as primary steel for basic structural members, i.e., piles, jacket legs and main structural cross bracings. The type 1 steel has a through-thickness ductility of between 15 and 20% elongation.

The steel BS-4369-43C normalized is the secondary structural steel, used in lesser significant structural elements of the jacket, but mainly on the decks and ancilliary structures.

Post Weld Heat Treatment (PWHT) in the U.K. Sector of the North Sea included the following areas:

- structural members in the splash zone over 50 mm thickness;
- nodes over 50 mm thickness in the submerged zone;
- structural members in the submerged zone over 63 mm thickness.

A.4 PRODUCTION PLATFORMS - GRAVITY - CONCRETE

For over sixty years concrete has been used in the construction of marine structures, like harbours, caves, fortifications, platforms and barges.

The first concrete gravity platform for drilling and production of oil or gas was for the Beryl 'A' Field installed in 1975, producing oil in 1976. The later Brent'B' and'D' platforms produced oil three years after the date of order.

The main features in which concrete platforms differ from the traditional steel pile platforms include:

- concrete is a corrosion-resistance material requiring no special maintenance;
- unanticipated top loads may be added in the operational stage without strengthening the concrete sub-structure;
- the concept of the gravity structure eliminates sea floor pilings;
- large deck areas and top loads can be accommodate;
- oil storage may be incorporated using the base buoyancy volume.

Among the major concrete gravity platforms, the Norwegian-contractors-built CONDEEP platforms represent perhaps the most innovative and effective ones. By mid 1981, six of such platforms were installed with the Stratfjord C platform currently under construction, see Table A-3.

A typical schematic representation of the Stratfjord 'B' CONDEEP platform is given in Figure A-9.

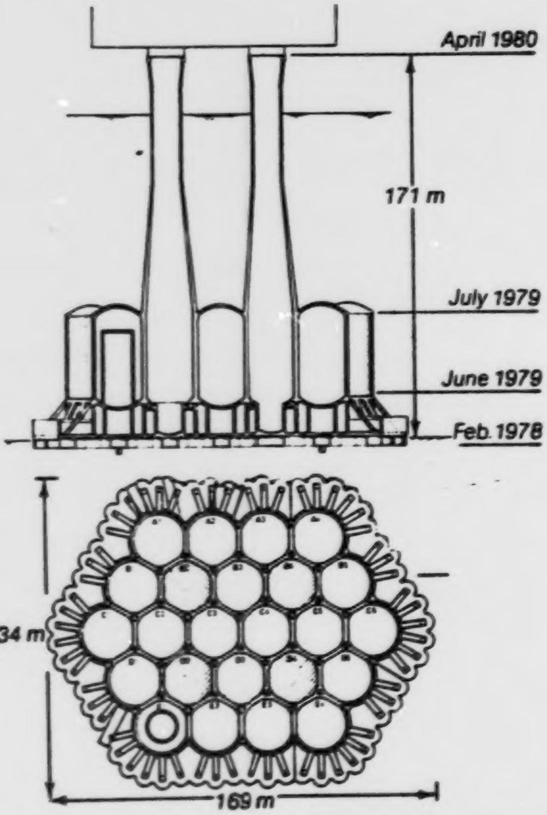
TABLE A-3

CONDEEPS built and under construction

Platform	*Waterdepth*	*Ordered*	*Installation*
Mobil – Beryl 'A'	*120 m*	*1973*	*1975*
Shell/Esso – Brent 'B'	*144 m*	*1973*	*1975*
Shell/Esso – Brent 'D'	*144 m*	*1974*	*1976*
Statoil/Mobil – Statfjord 'A'	*145 m*	*1974*	*1977*
Elf – Frigg TCP-2	*105 m*	*1974*	*1977*
Statfjord Group – Statfjord 'B'	*145 m*	*1978*	*1981*
Statfjord Group — Statfjord 'C'	*146 m*	*1980*	*1984*

FIGURE A-9

STATFJORD 'B' CONDEEP PLATFORM


April 1980
171 m
July 1979
June 1979
Feb. 1978
134 m
169 m

For several applications, the advantages of concrete gravity platforms are convincing to the extent that new designs for current and future use, particularly in deeper water applications, are being developed.
The ability of most of the concrete structures to integrate very cost effectively into the structure the storage of a multiple of daily production volume should have a particular appeal to the Canadian developments.

A novel and yet untried concept - that of an articulated buoyant column - was developed by Taylor Woodrow and dubbed ARCOLPROD. This sytem, suitable for water depths beyond 165 m could accommodate the following systems:

- drilling, production and storage systems for deep waters;
- satellite process and service platforms in marginal fields;
- riser for floating production systems;
- mooring, off-loading and integral subsea storage systems.

Extensive tests have been carried out by the Company on the novel universal type articulation joint made from a conically shaped series of strands of manmade fibre. The tip of the cone restrains the vertical column to the base template on the sea floor, see Figure A-10.

A type of gravity structure that could potentially be of particular interest to the Canadian East Coast operators is the one used in the Ekofisk Field.

FIGURE A-10

ARCOLPROD AND ITS ENLARGED BASE UNIT

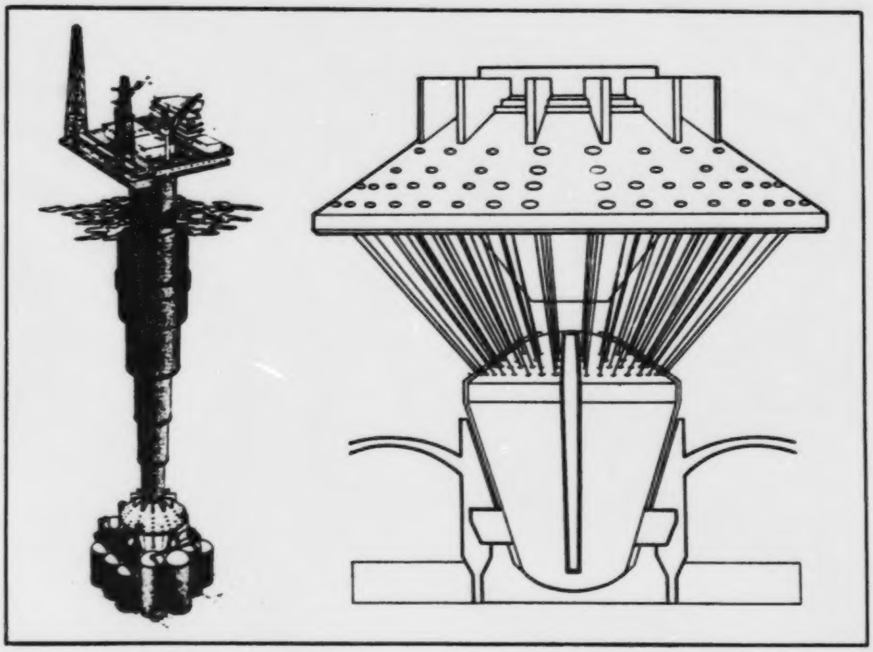
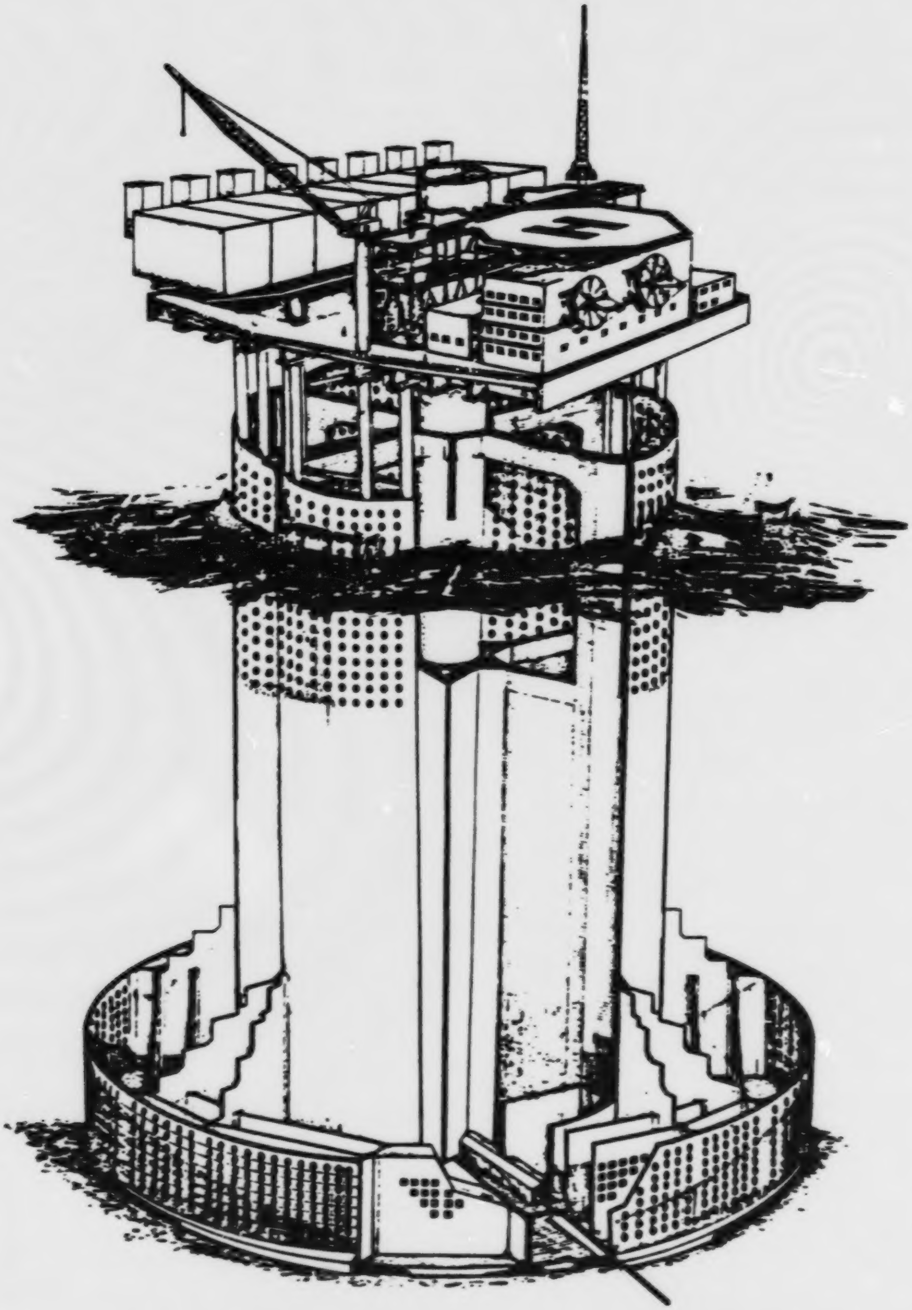


Figure A-11 gives a representative view of this type of platform which consists basically of three main subsystems. The circular raft foundation is designed as a reversed slab supported by the wall and diaphragms. The second subsystem is the vertical cylindrical component which is stiffened by a number of radial diaphragms. Its diameter is calculated so that the structure will float under the useful loads exerted during the various construction, towing and on-site installation phases. Its inner compartments are used for oil storage or as ballast tanks and it contains a cylindrical and hollow central shaft.

FIGURE A-11
SCHEME OF CONCRETE OFFSHORE PLATFORM



The sub-structure includes one or several decks with potential surface areas of up to 10,000 square meters.

The "trademark" of this type of structure is the uniform perforation of the outer wall which is a wave force reduction system, also called Jarlan Wall. These massive structures of over 60 m in diameter would experience unmanageably high overturning moments under the hundred year maximum wave design condition. The Jarlan Wall is said to absorb up to 50% of the wave energy.

To maintain the integrity of the concrete structures, an extensive inspection program is followed. (Browne, R.D. et al, 1981).

A.5 PRODUCTION PLATFORMS - FLOATING

Compared with the actual number of production platforms in operation, the floating ones are probably outnumbered by the fixed platforms (steel and piling, or concrete gravity) by a factor of 99:1. In the North Sea, only the Argyll Field and the Buchan Field use semi-submersibles.

The floating production platforms under planning or development are all semi-submersible platforms and in that are similar to the semi-submersible drilling rigs. However, because of the greater space and weight requirements for production equipment, the production semi's are larger in size and displacement. A compromise though is made with the two existing production semi's - the Argyll and Buchan systems - which are converted drill rigs. Generally, the practice of converting former drilling semi's to production platforms may continue for some time.

It could be expected that the currently constructed or developed semi's of the 4,000 tonne deck load class will be suitable to carry some of the added load of production and processing equipment.

Typically, a conversion for production use may include these requirements:

- accommodation of the hydrocarbon process equipment;
- permitting wire line or GFL service of template or satellite wells from the platform, while the production riser is installed;
- allowing workover of wells from the platform after the production riser is pulled;
- maximizing the increased carrying capacity of the semi-sub with minimal modification;
- utilization of the produced gas for fuel.

The major modifications resulting from these requirements may include the following -

- removal of:
  - . derrick with equipment;
  - . drill floor and sub-structure with all equipment;
  - . shale shake house with equipment;
  - . mud room equipment;
  - . pipe rack outfitting;
- install:
  - . turbo alternators;
  - . riser tension and deck with tensioners;
  - . riser handling system;
  - . subsea control system;
  - . flare tower;

- process plant with suitable enclosure;
- well injection plant;
- gas re-injection plant.

Of the many specific designs, Gotaverken Arendal's recently announced new semi-submersible production platform GVA-10,000 could be viewed as typical, see Figure A-12. This system is designed for intermediate and large fields featuring a platform carrying capacity of 12,500 tonnes of variable deck load, with crude oil storage capacity of 32,400 cubic meters, eliminating the need for separate storage facilities. (Figure A-13)

FIGURE A-12

ARTISTS RENDERING OF THE GVA-10,000

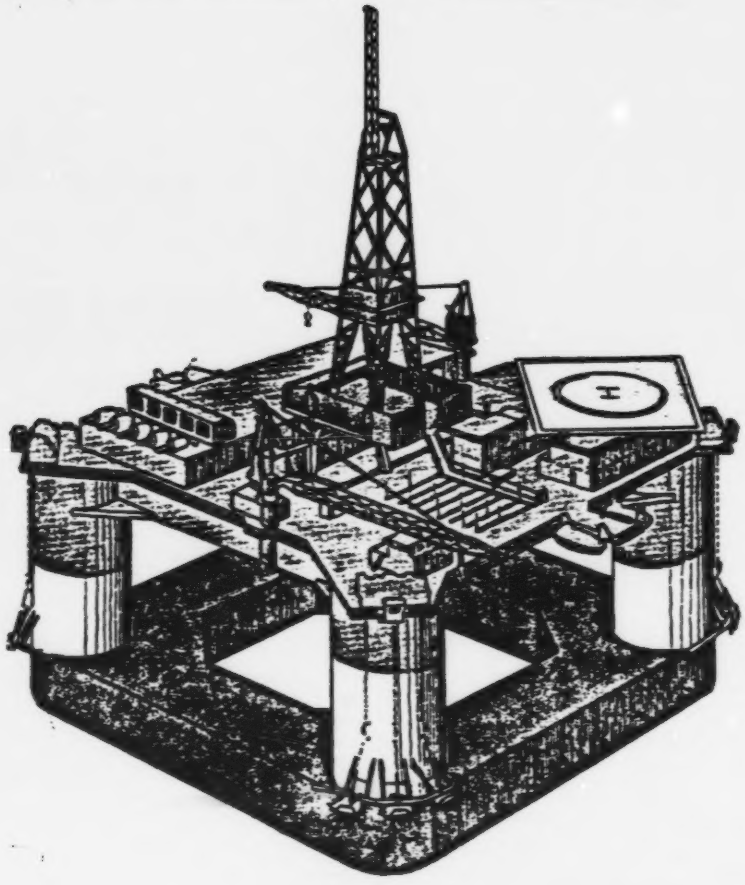
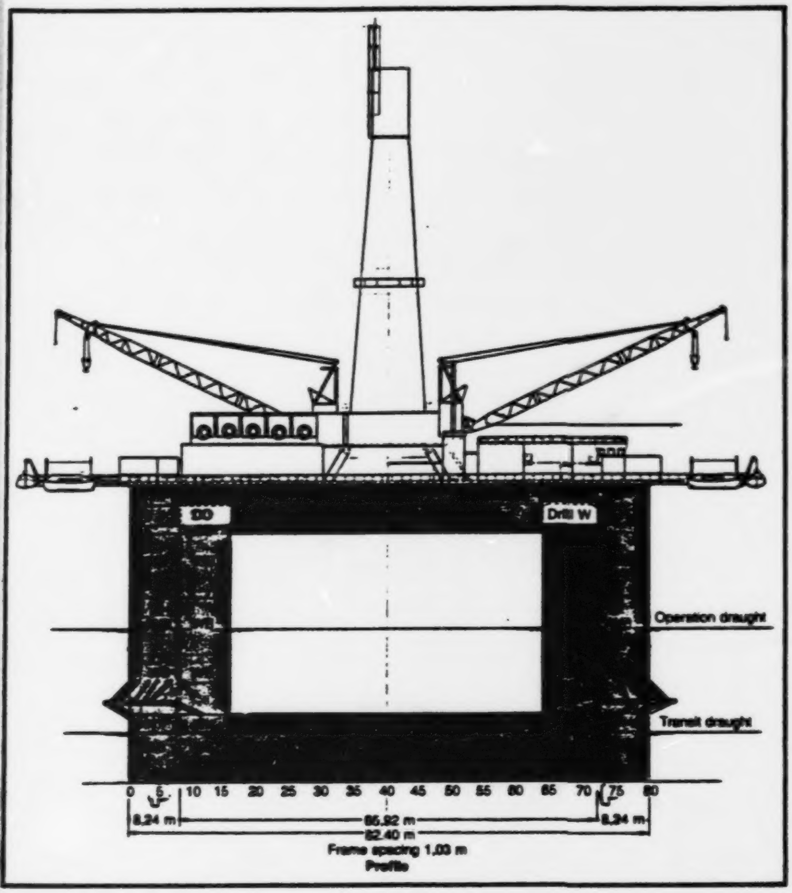
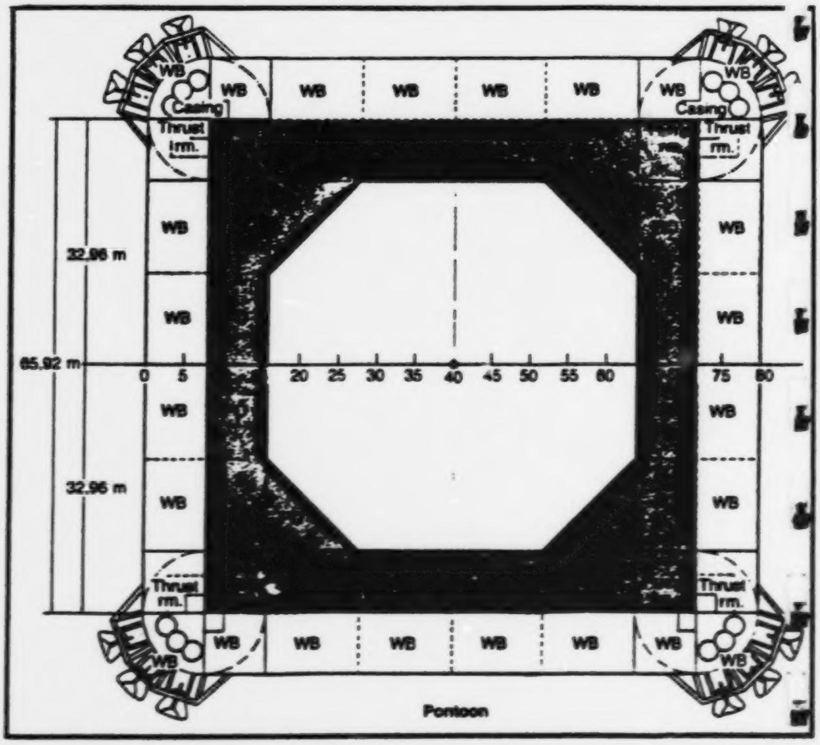


FIGURE A-13

GVA-10,000 -
ELEVATION AND PLAN


DO
Drill W
Operation draught
Transit draught
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
8,24 m
65,92 m
8,24 m
82,40 m
Frame spacing 1,00 m
Profile

SCHEMATIC OF SEMI UNIT showing storage location of drill water, diesel oil, and water ballast tanks.


WB
Casing
Thrust rm.
32,96 m
65,92 m
32,96 m
0 5 20 25 30 35 40 45 50 55 60 75 80
Pontoon

OVERVIEW OF PONTOON AREA, showing seperate compartmentalized tanks for

The platform features the unique design of only four platform legs supported on a single piece pontoon which is constructed as a horizontal square shaped ring of a box-like appearance. The platform is specifically designed for operation in ice areas and extremely severe wind and sea conditions, similar to those on Canada's East Coast. The structural and sea-keeping characteristics are designed to withstand 51.5 m per second winds and 35 m waves.

Pontoon and legs are split into water ballast tanks which are located at the outer perimeter of the pontoon and in the legs, yet all divided into small individual tanks, while the produced oil tanks are located on the inside of the pontoon, thereby reducing environmental pollution in case of oil tank breakage.
Figure A-13 shows elevation of the semi-submersible (top) and the plan of the pontoon area featuring the separate compartmentalized tanks for water ballast and crude storage.

Dimensions, operating characteristics, various capacities and other data are listed in Table A-4.

The Company indicates that the system is adaptable to operation in ice-infested waters, particularly suitable for medium size fields in 1,000 foot water depths and deeper.

TABLE A-4

GVA-10,000
DIMENSIONS AND OPERATING CHARACTERISTICS

PRINCIPAL DIMENSIONS

	Meters	Feet
Length overall	120.0	394
Beam overall	90.0	295
Height, keel to underside of main deck	47.5	156
Height, keel to top of lower deck	39.5	130
Length of pontoon	82.40	270
Beam of pontoon	16.48	54
Distance C/L of unit to C/L of pontoons	32.96	108
Depth of pontoon	11.00	36
Diameter of columns	16.48	54
Transverse spacing, C-C	65.92	216
Longitudinal spacing, C-C	65.92	216
Length overall about	113.0	371
Beam overall about	90.0	295

OPERATING CHARACTERISTICS

Water depth	460	1,500
Normal operating draught (from underside keel, excluding thrusters)	24.5	80
Survival draught	23.5	77
Transit draught	8.0	26
Air gap at still water for normal operating draught	15.0	49

PAYLOAD CAPACITIES

	Tonnes
Total deck load capacity in operating and survival conditions	12,500
The total deck load capacity can be distributed in the following manner:	
Marine equipment such as winches, cranes, life boats	
Accommodation	
Sanitary, ventilation	
Electrical	
Paint	2,700
Process equipment, drilling/workover equipment, diving complex, power generation	6,300
Variable deck load incl. icing	3,500
Total deck load capacity in transit condition	12,500

DECK AREAS

	m²	ft²
Total main deck area	6,000	64,600
Total 1:st tween deck area	3,700	39,800
Total 2:nd tween deck area	4,400	47,400
Total accommodation area	2,900	31,200

DISPLACEMENTS

	Tonnes
Normal operating condition	63,900
Survival condition	63,000
Transit condition	37,700

TANK CAPACITIES

The platform has a considerable capacity to store produced oil. Normal operating draught on the platform can be maintained with no oil stored or up to full tanks.

	m³	Barrels
Produced oil in pontoon tanks	21,000	132,930
Produced oil in column tanks	11,300	71,190
Total produced oil	32,400	204,120
Water ballast in pontoon tanks	23,380	147,072
Water ballast in column tanks	7,960	50,069
Total water ballast	31,340	197,141
Diesel oil column tanks	310	3,240
Drill water in column tanks	550	3,456
Potable water on second tween deck	260	1,635

A.6 PRODUCTION PLATFORMS - TENSION LEG/ARTICULATED BUOY/ GUYED TOWER SYSTEMS

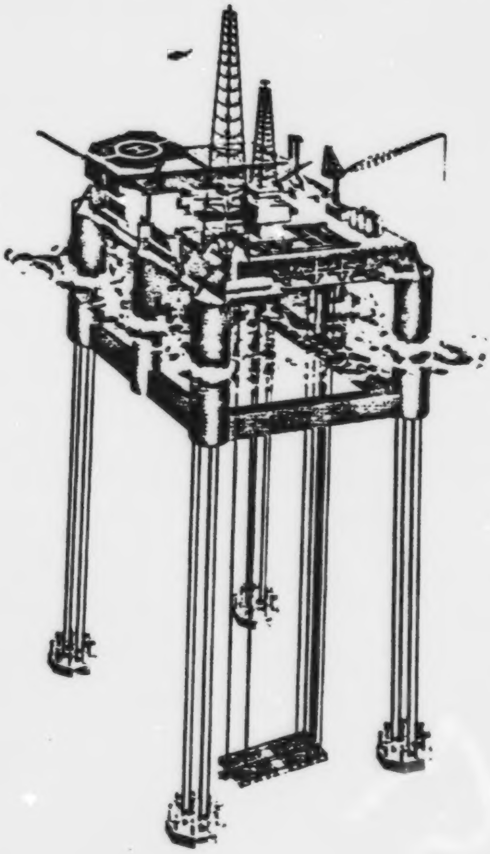
Tension leg platforms (TLP) have been under design and development for application in the North Sea for several years. The first to be installed is Conoco Oil's Hutton Field platform. Its template having been installed in early 1982, the specifically designed semi-submersible floating platform is scheduled to move on to location by 1983 and production to start before 1984.

Another strong proponent of this type of system has been B.P., who have developed their tethered buoyant platform production system since 1975.

While Chevron has announced only recently its evaluation work of TLP systems for future production in the Santa Barbara Channel, Tecnomare have geared their TLP developments to water depths of over 1,000 m in a Mediterranean Sea environment. For this application, it would have an operational payload of about 26,000 tonnes.

The Hutton tension leg platform of Conoco Oil, Figure A-14, will be installed in extremely rough 160 m waters, and will be watched very carefully by all offshore oil operators. Of particular interest are the installation of the entire system including the drilling of the production well and the ease of operation, the in-service inspection and the maintenance requirements. If this prototype lives up to the expectations, oil and gas production will likely be expanded into waters ranging to 700 m or more, with a possible later expansion to 2,000 m. Unlike fixed platforms, TLP costs are relatively insensi-

FIGURE A-14
THE HUTTON TENSION LEG PLATFORM



tive to water depth. The structural members that link the platform with the sea floor will be in tension rather than compression and their length will have far less structural significance than in a bottom-supported platform. The added expense for deeper waters will be the longer tension legs, risers, casing and offsetting buoyancy.

Additional advantages include:

- the new floating platform can be towed to a location, can be temporarily moored then anchored to the sea floor without diver assistance;
- some of the development wells can be predrilled while the TLP is being constructed;
- the mooring tethers which can be described as oversized drill pipes can be removed for inspection from time to time;
- when a field is depleted, everthing from the sea floor and up can be recovered in a short time;
- once permanently moored on location, vertical motions - heave, roll and pitch - are virtually eliminated;
- the maximum lateral excursion in the most adverse sea conditions will, at least for the Hutton platform, be only 24 m;
- because of the TLP's semi-submersible configuration, it can be towed in almost any kind of weather;
- it can be removed from the field including tethers, anchors, template and the other subsea equipment within a few days.

Conoco indicates that the cost of the TLP compares quite favourably with that of a fixed platform. Its installation cost is very low as will be its removal cost.

Removing of the platforms after the fields are depleted has only recently become an issue in the North Sea oil production areas. For a fixed platform, the removal represents an expenditure about equal to, or even larger than the original installation cost, which will adversely affect the economics.

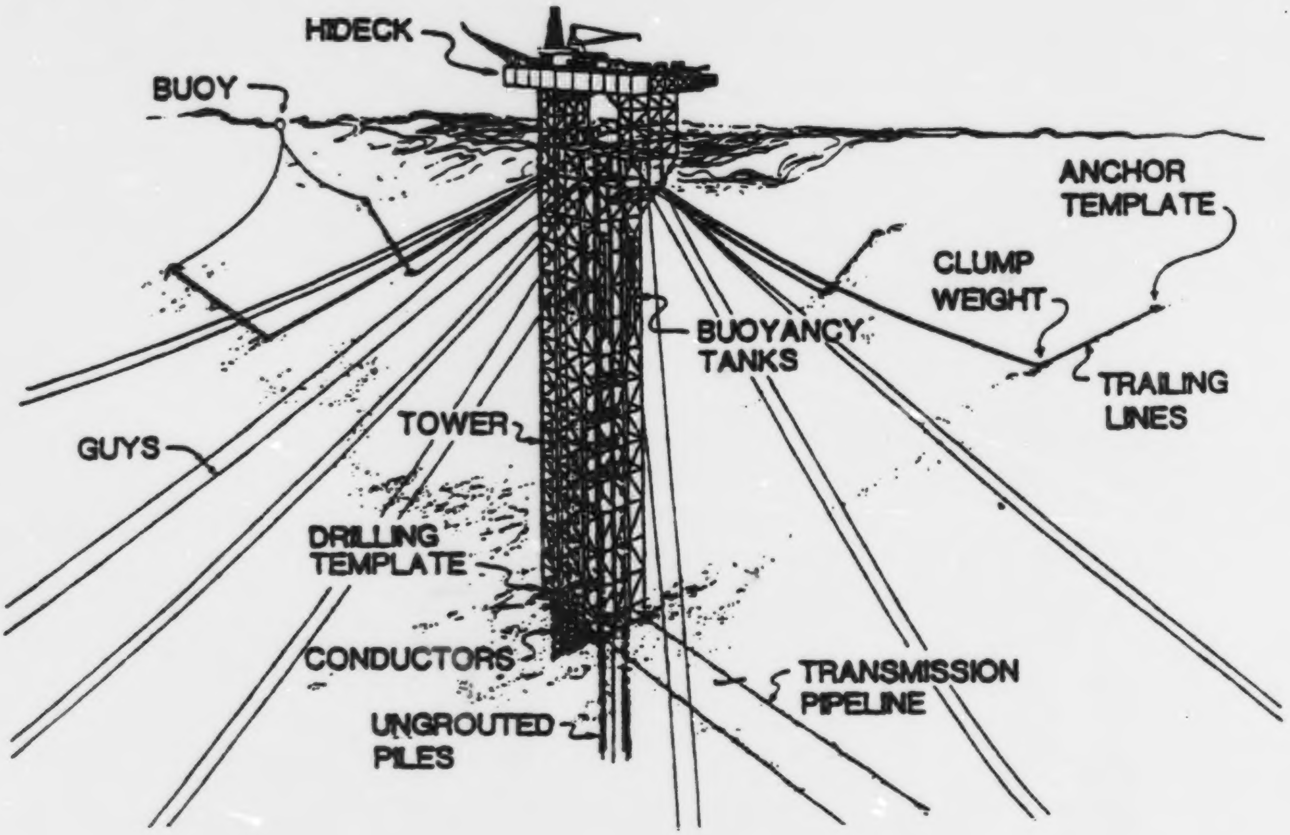
The guyed tower concept, Figure A-15, is compliant in that it is designed to move slightly in response to the dynamic forces acting upon it. It transmits primarily vertical gravity loads to the sea floor, imposed by the drilling and production equipment. At the sea floor it is supported by a bearing foundation or a more conventional piled foundation. Stability of the tower is assured by guyed lines that run through fair leads to clump weights on the sea floor with an additional extension to anchor piles. Wave forces are passed directly to the guy lines and, as a result, the tower is not required to transmit large over-throwing moments to the base as does a conventional fixed platform. A guyed tower's deep water application is enhanced by its compliant response to the guy line system:

- in moderate sea states, the clumps remain on the sea floor with the guy lines taut;
- in severe sea states, the tower oscillations become larger and the clumps progressively lift off of the sea floor, thereby causing a softening of the guying system.

Consequently, two significant effects are producted in that the sway period is lengthened, reducing dynamic wave structure interactions, and the increasing motion causes relatively high structural velocities, resulting in decreased wave forces on the structure.

FIGURE A-15

THE GUYED TOWER CONCEPT


HIDECK
BUOY
ANCHOR TEMPLATE
CLUMP WEIGHT
BUOYANCY TANKS
TRAILING LINES
TOWER
GUYS
DRILLING TEMPLATE
CONDUCTORS
TRANSMISSION PIPELINE
UNGROUTED PILES

To date, no such systems have been installed, or are seriously considered. It appears that at depths of 600 m and below, the amount of steel required will make this system economically unattractive.

A.7 SUBSEA PRODUCTION SYSTEMS, STORAGE SYSTEMS AND OIL TRANS-SHIPMENT SYSTEMS

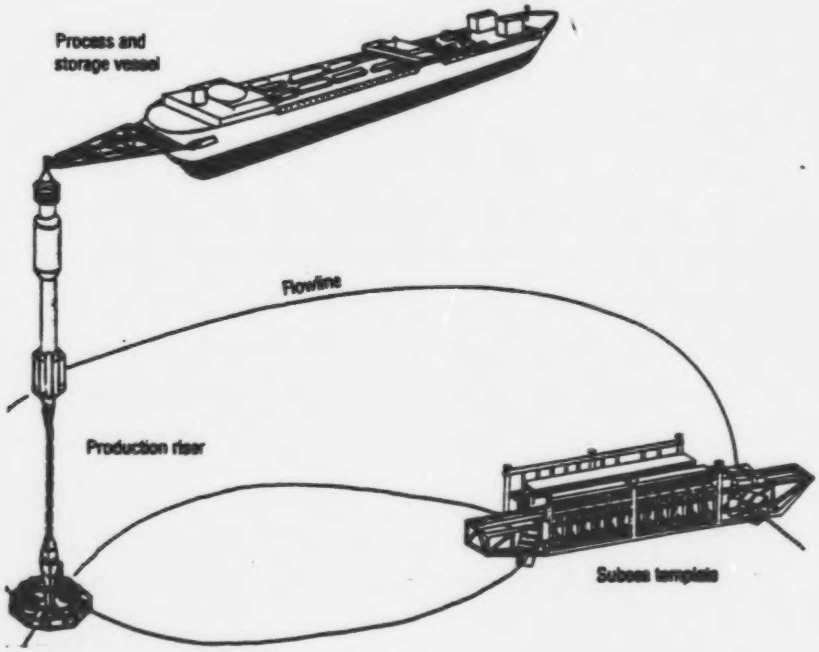
The use of thick steel plate in subsea production systems is negligible. However, they may become the future major competition to platform-based production systems. While such potential production from subsea systems is possible in the distant future, particularly for the Canadian offshore oilfields, it may be considered significant to monitor any trends toward these systems with respect to future investment in steelmaking or fabrication plants.

While there are many developments at various stages of maturity, one significant event is Shell/Esso's decision to install its advanced underwater manifold centre (UMC) in the Central Cormorant field in the U.K. Sector of the North Sea. This system could also be installed in water depths of 1200 m, requiring little modification.

Exxon has proved the technical viability of its submerged production system (SPS) which is designed for 620 m water depths. Figure A-16 shows the system arrangement, the sea floor template, the flow lines, production riser and hook-up to process and storage vessel.

FIGURE A-16

EXXON SUBMERGED PRODUCTION SYSTEM



Almost exclusively, all production systems which are not hooked to an export pipeline require some sort of storage capability. As the alternative to pipelines, tankers will automatically cause an interruption in the oil production if only for the time of switching the loading connections from one to the other. To accommodate interruption in the shuttle tanker schedule, for reasons of weather, mechanical or otherwise, operators are planning on storage volumes that represent the capacity for several days production.

The storage concepts include surface vessel, vertical columns and tanks of steel, rubber or concrete laid on the sea floor. Neither requires any significant amount of thick steel plate.

A.8 PROCESSING PLANTS

Of interest in this section are barge or otherwise mounted processing plants for conversion of natural gas to liquefied natural gas or methanol or ammonia or any other liquid. Further, of interest could be the function of storing these liquids as well as crude oil. However, in any case, the barges or platforms for these plants would have to be used in waters which require ice reinforcement to some extent.

Of the many published barge-plant concepts, the Canadian Arctic Pilot project barges could be representative. Currently undergoing hearings, the project will contain one barge mounted liquefaction plant for operation at the Brideport Inlet facility and two LNG storage barges at the same site.

These three barges will be double-hulled up to the level of the free board deck with the outer hull being protected against corrosion in operation by epoxy coatings and by impressed current cathodic protection. They will be built of low temperature steel and reinforced to withstand ice pressure during towing to Brideport Inlet. The LNG plant barge will be 135 m long, 32.3 m wide, have a depth (to main deck) of 15 m and an overall height of 28 m. Its draft under towing operation will be 5m, and while operating, 4 m.

Each of the two LNG storage barges will contain 100,000 cubic meter capacity and will show the following dimensions:

- length - 175 m;
- maximum breadth - 36.5 m;
- overall height - 24 m;
- draft (towing) - 6 m; and,
- draft (berthed) - 3 m.

A.9 BEAUFORT SEA TYPE EXPLORATION AND PRODUCTION SYSTEMS

A large variety of artificial structures for exploration and production work in the Beaufort Sea have been suggested. Many were studied in detail, and to date, only a few are in serious planning for current or future use.

In the following description, systems for exploration and production are treated together, for it appears now that some of the drilling structures will be used as bases for production facilities.

Two main reasons were responsible for the development of artificial islands as they are today - firstly, the fact that the water depth in the Beaufort Sea gradually slopes from 0 to less than 30 m over a distance of 100 km, and secondly, that early indications of hydrocarbon resources were found at shoreline and water depths of less than 25 m. Resulting were the construction of several sand dredged and rock-armoured artificial islands of extremely shallow slopes, the first of which was built by Imperial Oil in the early 1960's.

Pilot structures for the Beaufort Sea can be characterized as follows:

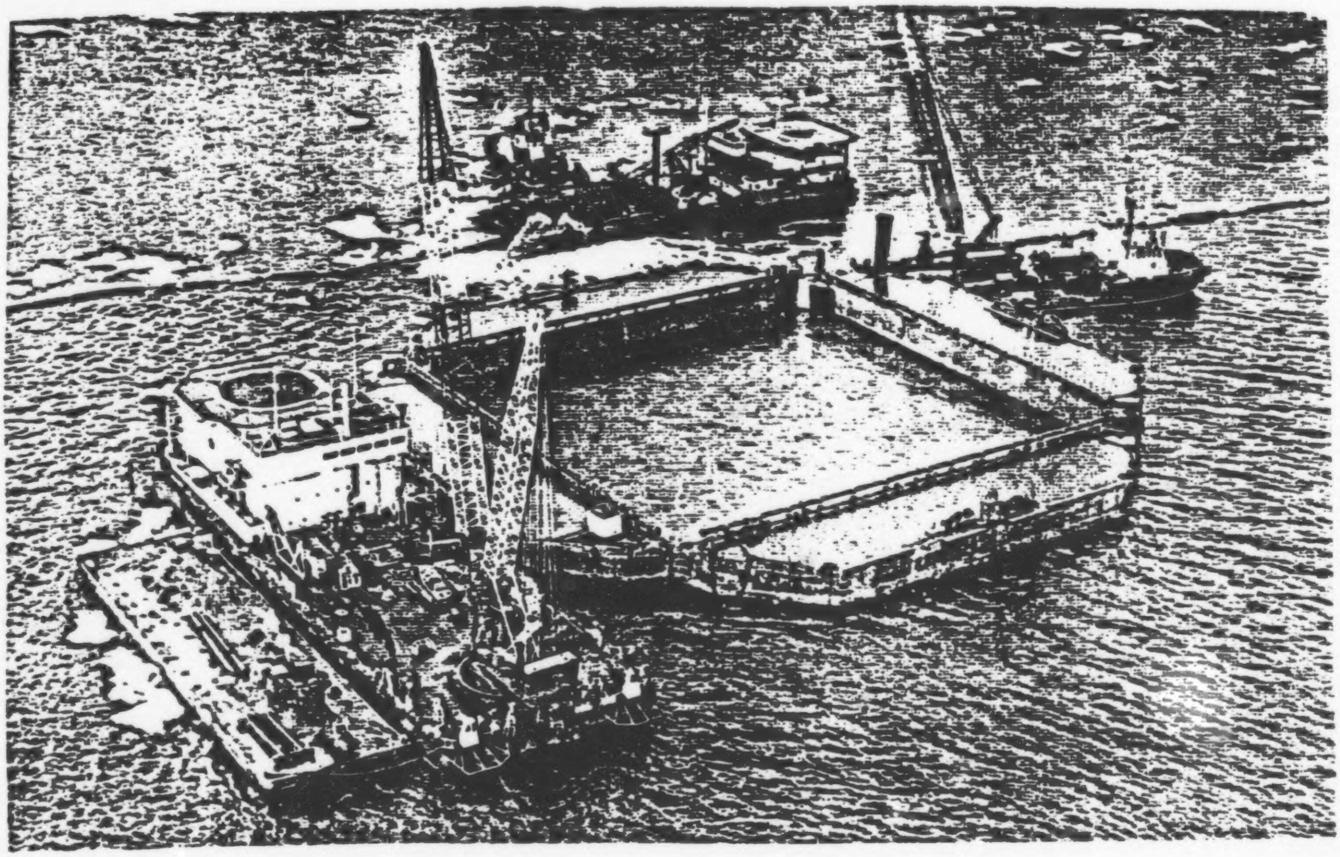
- sand dredged islands with various slope systems and slope protection;
- caisson-retained islands with sand fill;
- entirely pre-fabricated caissons in single or multi-piece construction, which are furnished with decks and floating/ballast storage containers;
- four variations of pre-fabricated caissons in single or multi-piece construction ranging from a single piece floatable drilling unit to the multi-structure type monocone production system;
- floating drill units including ship-shape, conical and/or circular.

Many of these structures can be fabricated from either steel or concrete.

The sand dredged island is not further considered here, but the caisson-retained island of the Tarsiut type will be. Figure A-17 shows an overall impression of the size of Tarsiut Island during construction. Each caisson is

FIGURE A-17

TARSIUT ISLAND DURING CONSTRUCTION



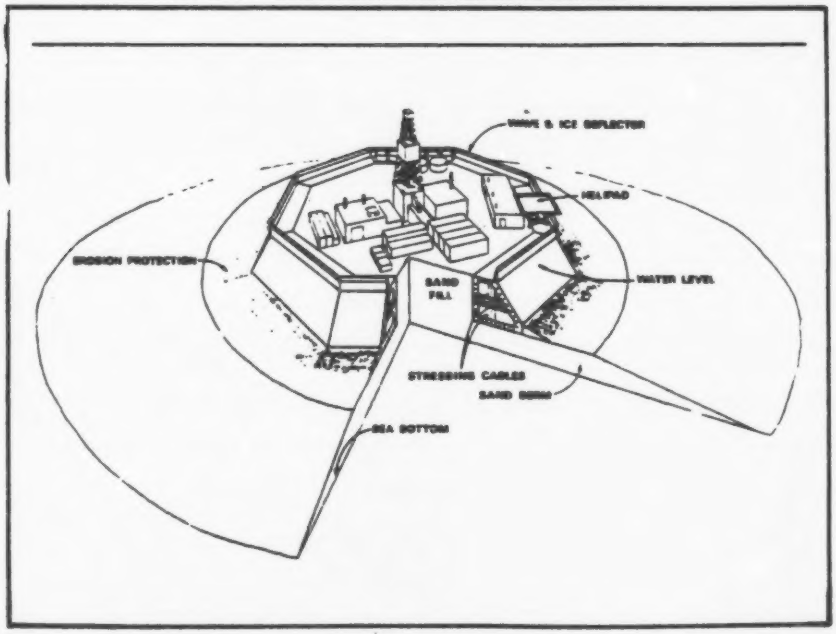
11 m deep, weighing 5300 tonnes and is fabricated from steel reinforced concrete. The island was completed in 1981 and began drilling operation during the winter of 1981/82, as well as extensive testing. It, and other islands of the type that follow will possibly provide the basis for constructing around it major production facilities.

Esso has currently under construction in a Japanese shipyard, a steel-based octagonal shaped multi-piece caisson which features a patented connection system of the eight caissons, namely, strands of wire ropes that couple the eight caisson sections together. Figure A-18 is a representation of the island when installed. Figure A-19 shows a typical caisson ring assembly and caisson frame details.

The third caisson based exploration island currently under production is that of Gulf Canada Resources, being fabricated by Ishikawhaima-Harima Heavy Industries (IHI) and Mitsui and Co. Its dimensions are 111 m x 111 m in the lower sections and 86.6 m x 86.6 m in the upper section. Its total height is 29 m for a water depth of 21 m, with a total weight of about 33,000 tonnes. This caisson is built as one piece which will be floated to its locations in the Beaufort Sea. Dubbed the Mobile Arctic Caisson (MAC), the caisson features ballasting systems allowing the caisson to be re-flooded after drilling completion for floating to the next site, Figure A-20.

FIGURE A-18

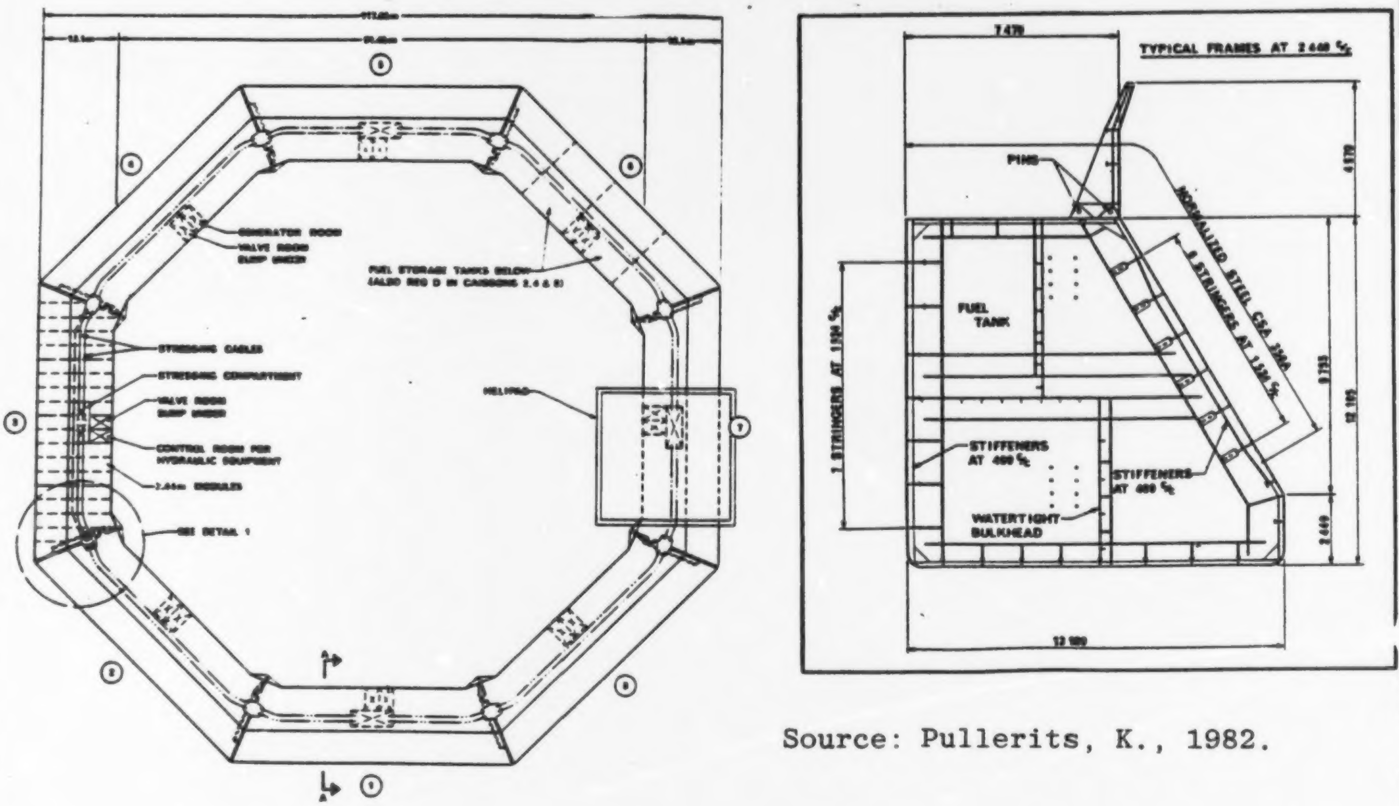
ESSO'S MULTI-PIECE CAISSON


WAVE & ICE DEFLECTOR
HELIPAD
EROSION PROTECTION
SAND FILL
WATER LEVEL
STRESSING CABLES
SAND BERM
SEA BOTTOM

Source: Pullerits, K., 1982.

FIGURE A-19

TYPICAL CAISSON RING ASSEMBLY AND CAISSON FRAME DETAILS


GENERATOR ROOM
VALVE ROOM SUMP UNDER
FUEL STORAGE TANKS BELOW (ALSO REQ D IN CAISSONS 2,4 & 6)
STRESSING CABLES
STRESSING COMPARTMENT
VALVE ROOM SUMP UNDER
CONTROL ROOM FOR HYDRAULIC EQUIPMENT
2.44m MODULES
SEE DETAIL 1
HELIPAD
A
A
7 470
TYPICAL FRAMES AT 2 440 C/C
PINS
4 570
NORMALIZED STEEL CSA 350A
8 STRINGERS AT 1 320 C/C
FUEL TANK
7 STRINGERS AT 1 320 C/C
STIFFENERS AT 400 C/C
STIFFENERS AT 400 C/C
WATERTIGHT BULKHEAD
2 440

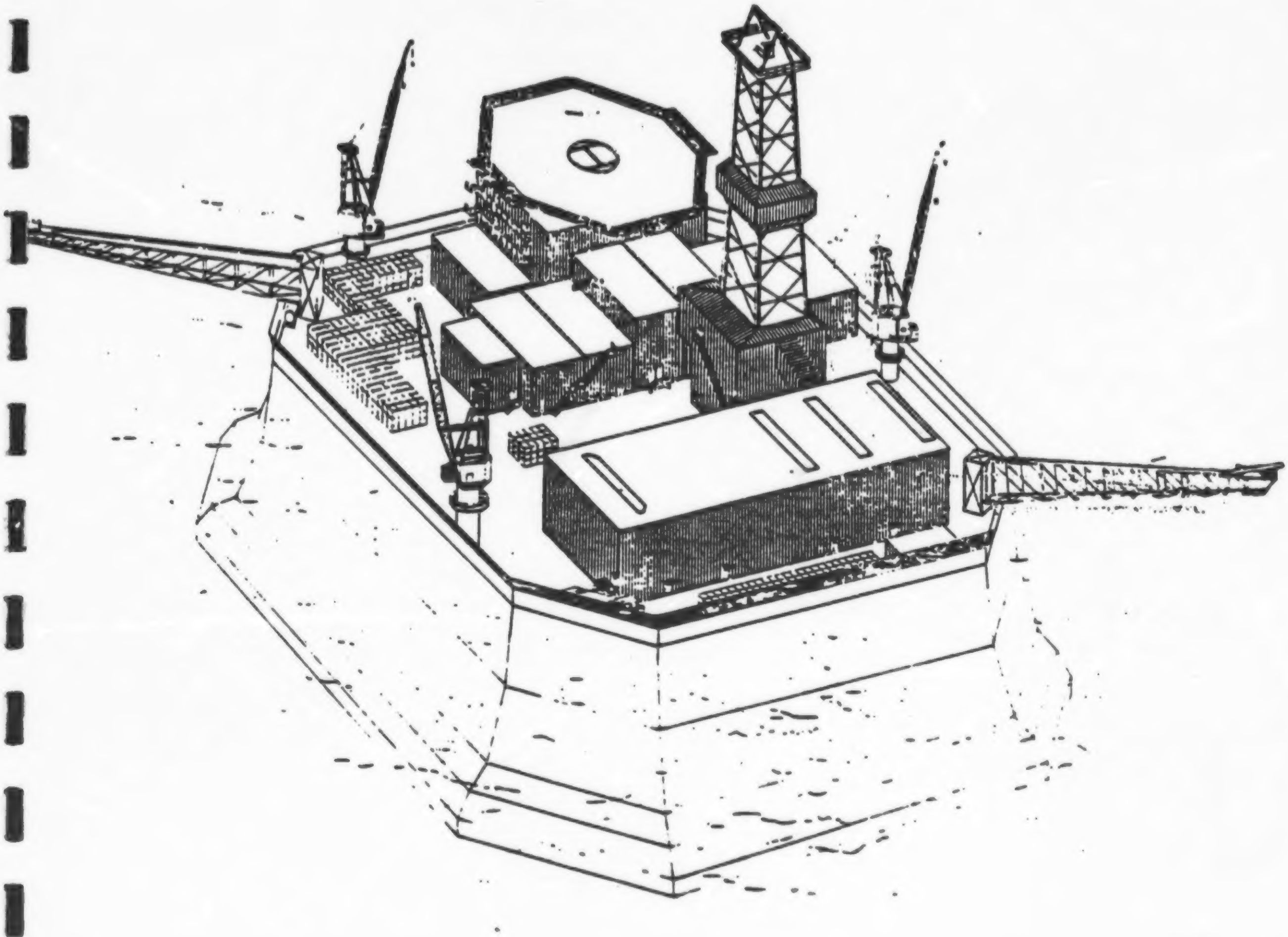
Source: Pullerits, K., 1982.

- A variety of other concepts have been investigated in detail, including versions of Arctic monocones in steel and in concrete.

While neither is under serious consideration at this time, certain advantages of these designs may increase their desirability in the future.

Of such production systems investigated for deeper waters of about 160 m, Dome evaluated this concrete gravity caisson shown in Figure A-21.

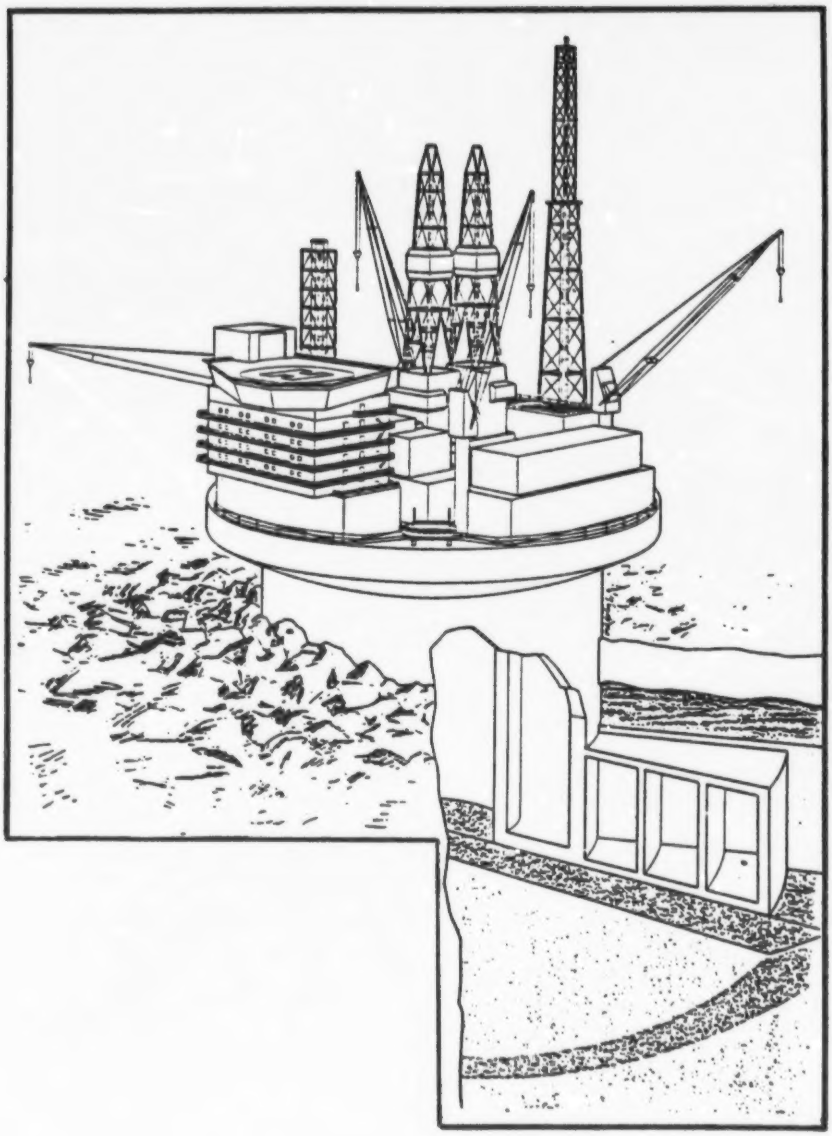
FIGURE A-20
MOBILE ARCTIC CAISSON (MAC)



Dome's recent plans for the exploitation of its major three fields - Tarsiut, Koakoak and Kopanoar is based on the further extension of the Tarsiut exploration island, the fully completed Arctic Production and Loading Atoll, (APLA). APLA's will likely not require any thick steel plates.

FIGURE A-21

CONCRETE GRAVITY CAISSON



A.10 ARCTIC ISLAND TYPE EXPLORATION/PRODUCTION SYSTEMS

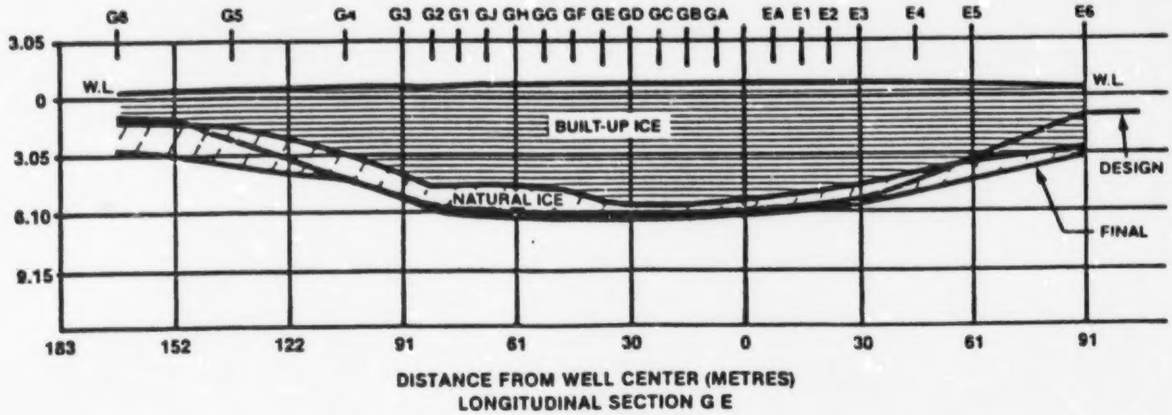
Traditionally, exploration in the Arctic Islands area has been carried out from artificial ice islands. The limited amount of production installations are sea bottom systems with pipeline to shore. While Pan Arctic, the main operator in the Arctic Islands area, has discovered significant quantities of crude oil in various wells, only natural gas is of commercial interest at this time.

Drilling takes place only during the winter and then only after the ice island thickness has been built up well enough to carry the load of the derrick and associated drilling equipment. This point is reached usually in January, with demobilization before thawout, commonly in May.

The construction of such an artificial ice island begins with intermittent flooding of a selected area on top of natural ice until the desired thickness is reached, typically 6 to 7 m. (Hood, G.L., et al, 1981). Figure A-22 is a cross section of the Drake F-76 Ice Platform.

FIGURE A-22

DRAKE F-76 ICE PLATFORM


G8
G5
G4
G3
G2
G1
GJ
GH
GG
GF
GE
GD
GC
GB
GA
EA
E1
E2
E3
E4
E5
E6
3.05
0
3.05
6.10
9.15
W.L.
W.L.
BUILT-UP ICE
NATURAL ICE
DESIGN
FINAL
183
152
122
91
61
30
0
30
61
91
DISTANCE FROM WELL CENTER (METRES)
LONGITUDINAL SECTION G E

A.11 ARCTIC VESSELS

The voyage of the S.S. Manhattan in 1969 has demonstrated that large ice-breaking vessels could well manoeuver in the Canadian Arctic environment, potentially transporting the Arctic's hydrocarbon resources to southern markets.

Ever since that time with the increased interest of the exploration companies in the Arctic, both basic transportation routes - tankers and pipeline - have been competing.

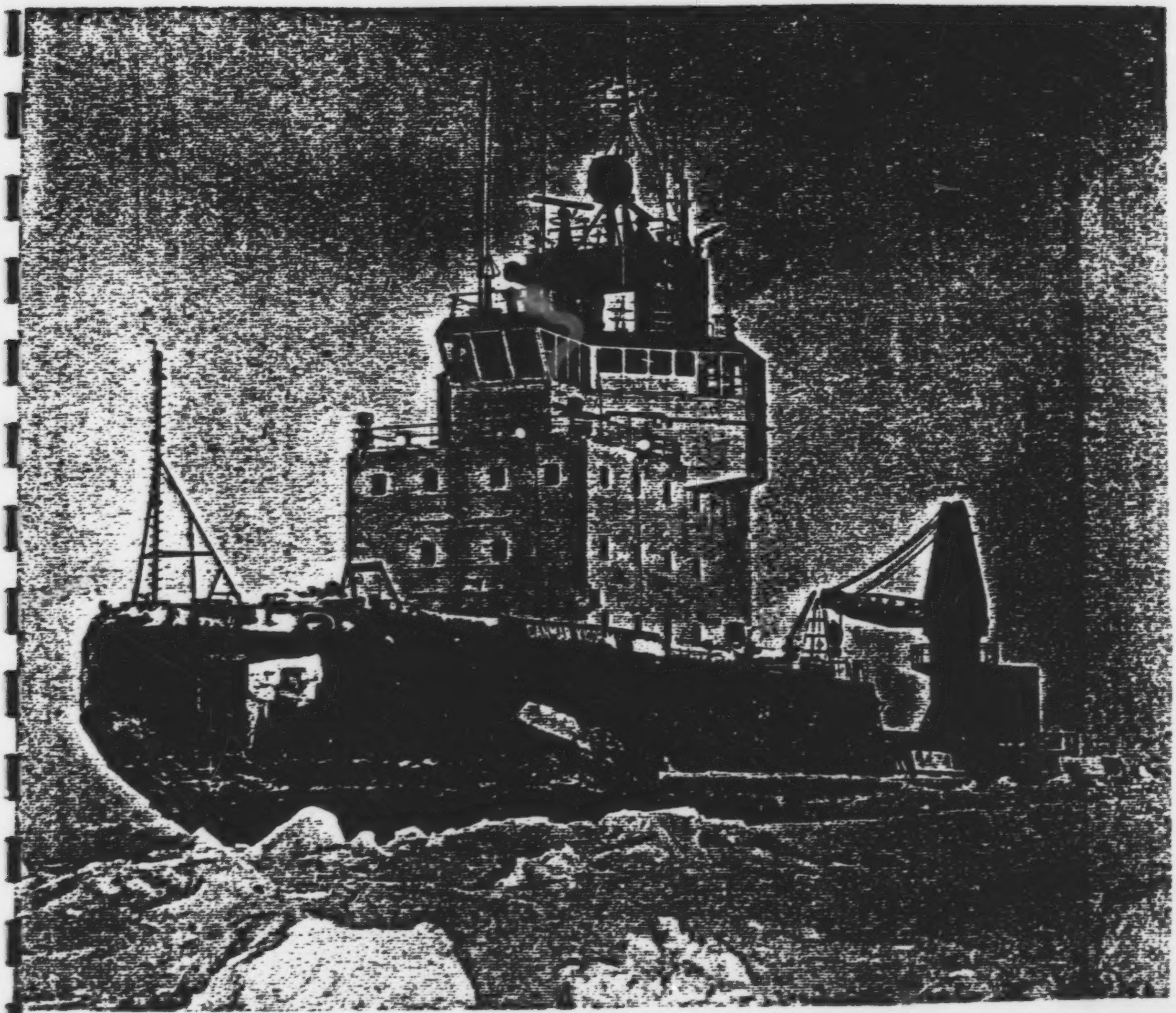
The ice-breakers currently operating or under construction include Dome's "Kigoriak", Figure A-23, an Ice Class 4 vessel of about 90 m length, 19 m width, 10 m depth, 16,400 s.h.p. power, 7,000 tonnes displacement, with a complement of 34 persons and a bollard pull of 190 tonnes. The "Kigoriak" is basically an experimental ice-breaker, whose first mission was to assist Dome's drillship fleet Canmar Explorers I, II, III and IV, which was followed by a sophisticated and minutely detailed research program in the Arctic. The Company anticipated the vessel to be a forerunner of its future ice-breaking tanker fleet in several of its very specific novel features, e.g., its ice-breaking bow.

In Summer, 1982, Dome is expecting to take delivery of its Supplier 9, of Arctic Class 3, to be called the "Robert LeMeur", which is currently being built by Burrard-Yarrows in Vancouver. The vessel will be "state-of-the-art" in ice-breaking technology, powered by two 6,000 h.p. diesel engines driving two propellers.

Aside from these two vessels specifically designed for use in the Beaufort Sea developments, Petro Canada has

FIGURE A-23

DOME'S ICE-BREAKER - "KIGORIAK"



ordered a geophysical ship with an ice-strengthened compartmentalized hull of 1600 tonne displacement for work in the Arctic during summer months. It will be fabricated by Marine Industries Ltd., of Sorel, Quebec for delivery in May, 1983.

The newest ice-breaker operated by the Canadian Coast Guard - the "Pierre Radisson" - is an Arctic Class 3 ice-breaking vessel with a full load displacement of 7,721 tonnes, 13,600 h.p., a cruise speed of 7 m/s and a complement of 57 persons, Figure A-24. Its sister ship is the "Sir John Franklin". Both were built in Vancouver, B.C. in the late 1970's.

Other ice-breakers of various classes are operated mainly by the Canadian Coast Guard, the largest being the "St. Laurent", a Class 4 ship of 24,000 h.p., single shaft.

For discussion of ice-breaking tankers, an introduction to the Arctic Shipping Pollution Prevention Regulations (ASPPR) is provided in the following.

ASPPR defines the minimum requirements for the design and safe operation of all vessels transitting the Canadian Arctic. The terminology of the regulations described ships by class: A Class 4 vessel is one that can travel at 3 knots in ice of 4 foot thickness, or a Class 10 vessel to break ice of 10 foot thickness while cruising at 3 knots. The regulation further divides the Arctic into zones as per Figure A-25, based on information that was available in 1970 on ice thickness, type and frequency.

FIGURE A-24
THE CANADIAN COASTGUARD'S - "PIERRE RADISSON"

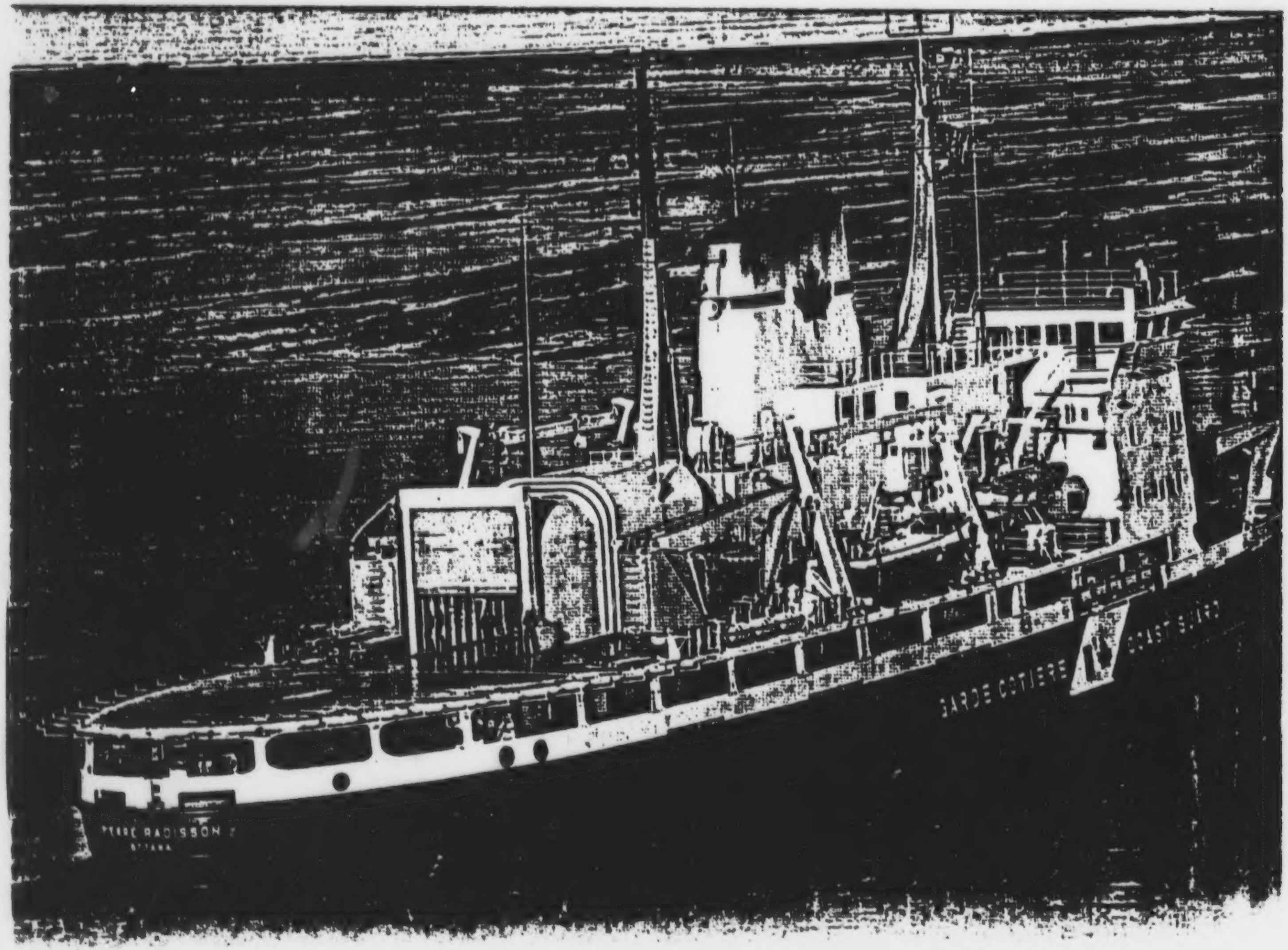
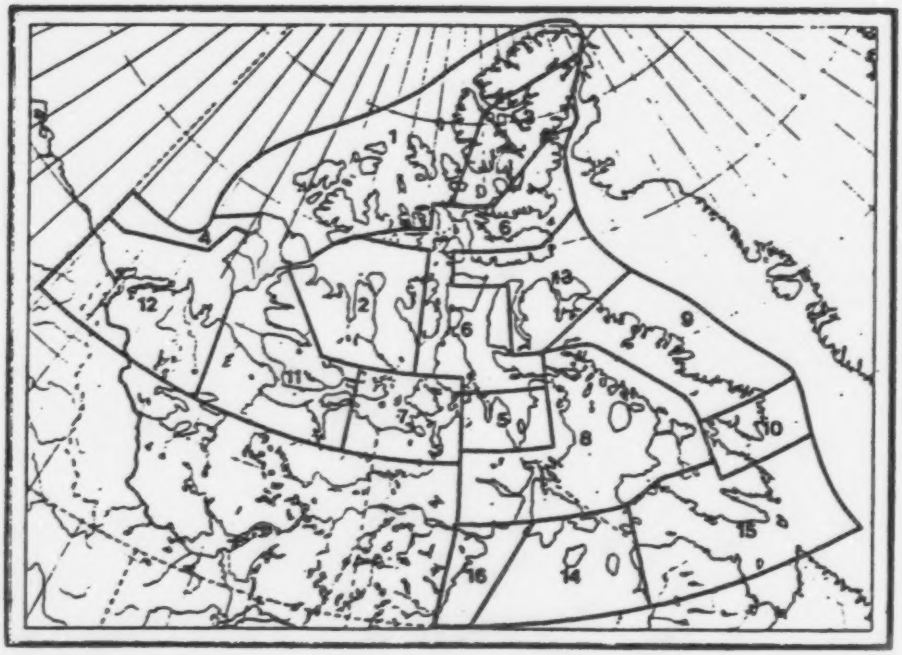

GARDE COTIERE
COAST GUARD
PIERRE RADISSON
OTTAWA

FIGURE A-25

(CASPPR) ARCTIC ZONES



In addition to the design efforts of the Melville Shipping Group on the ice-breaking LNG carrier for the Arctic Pilot Project, Dome Petroleum is far ahead with the development of its very large Arctic Class 10 oil tanker. This Dome tanker is designed to carry 200,000 tonnes or 1.5 million barrels of oil (equivalent to approximately 50,000 barrels of oil per day of production). The ice-breaking hull of the vessel will meet all of the Canadian Coast Guards's requirements for year-round operation anywhere in the Arctic. It will be double-hulled, with the oil stored in centre tanks isolated from the outer hull by twelve 10 m wide water ballast tanks, (depending on location) in the hull. The engine power of the vessel is about 150,000 h.p. It will be equipped with highly advanced ice navigation equipment. Current cost estimates are $350 million (1981 dollars) over a two-year construction period.

Additional background on Dome's plans for its Arctic vessels is given in its Senate Presentation, 1982.

The Arctic tanker will be 390 m long, 52 m wide and have a draft of 20 m. The cruising speed will be 10 m/s in open water and 3 m/s in 3 m ice. This performance will exceed the Class 10 standards for ice-breakers which require only a 1.5 m/s speed in 3 m ice for Class 10 vessels. (Beaufort Magazine, February, 1982).

The LNG carriers for the Arctic Pilot Project will be Arctic Class 7 Ice-breakers of 375 m length, 43 m beam, an LNG capacity of 140,000 cubic meters and power levels of 180,000 h.p. Two of the ships are planned for the project that will produce 7.1×10^6 m^3/d. They too will feature a double-hull construction, protecting the low temperature liquefied natural gas cargo from the ice and water by water ballast tanks.

Some particulars of the multi-purpose cargo ships recently ordered by V/O Sudoimport of the Soviet Union for operation in the Soviet Arctic may be of interest. These vessels will be able to operate without assistance in extremely rigorous temperatures down to $-50^{\circ}C$. They will have a length of 174 m, breadth of 24.5 m, deck depth to upper deck 15.2 m, Arctic draft 9 m, maximum dead weight 20,000 d.w.t., Arctic dead weight 14,700 d.w.t. and a speed in open water of 9 m/s.

Among the newer developments in Arctic operations could be air cushion type vehicles utilizing the ice-breaking capability of its hovering system. (Offshore Magazine, 1982-2).

While it may sound like science fiction, the recent suggestions of an otherwise not so new concept, the submersible tanker for LNG or oil, warrants a good deal of thought. Consider on the one hand, the enormous amount of effort to be spent by Canada in the development of the Arctic Class 7 to 10 LNG carriers and oil tankers in order to make them as operationally practical and safe as desirable, and then evaluate the technology already developed and proven for military submarines. In the first case, it can be assumed that for the high Arctic Class vessels involving several new technological steps (better steels, higher welding quality, system of double-hull, extreme amount of power levels, vast amount of logistics required to operate such plants by private industry), will require considerably more funds than currently estimated. The submarine tanker, could, however, require less additional technology for the only major requirement would be to extend its size to an economical level. It is not clear that it would have to be in the order of 100,000 cubic meters carrying capacity for either LNG or crude oil.

The Coast Guard's new projects include the 100,000 h.p. Polar 8 Ice-breaker. If built, it would be the most sophisticated and most powerful ice-breaking vessel of the Coast Guard fleet. The vessel is designed to satisfy a wide spectrum of operating conditions:

- maintain 3 knots in consolidated packed ice up to 2.4 m thick;
- break consolidated multi-year polar ice of up to 8.5 m thick;

- fulfill missions of up to 23 full days at full power, including storage and provisions for 175 persons for up to 270 days;
- provide a high degree of manoeuverability for work in close proximity with ice-bound ships;
- a general search and rescue operation.

At this time, the Coast Guard is hoping for a vessel completion by 1987/88, given approval by Cabinet in Summer, 1982. Future plans include the possible construction of a Polar 10 vessel primarily for year-round operation in the Sverdrup Basin, and available for operation in the mid-1990's. Table A-5 gives comparative data for Polar 8, "R" Class and St. Laurent.

TABLE A-5

COMPARATIVE DATA FOR COAST GUARD VESSELS

	POLAR 8	"R" CLASS	ST. LAURENT
Length overall (metres)	194.0	98.3	111.7
Length B.P. (metres)	173.5	87.9	24.4
Breadth moulded (metres)	32.2	19.5	13.1
Depth to main deck (metres)	18.75	8.1	13.1
Load draft (metres)	13.0	7.2	9.4
Speed (cruising) knots	15	13.5	13
Cruising range N.M.	30,000	15,000	22,000
Shaft horsepower	100,000	13,600	24,000
Full load displacement (tonnes)	37,000	7,721	14,500
Deadweight (tonnes)	12,300+	2,820	4,718
Fuel oil capacity (tonnes)	10,000	2,215	3,632
Endurance @ full power output (days)	20-23	30	13
Crew	116	54	81
Total berths	175	76	209
Propulsion system	AC/AC CODAGE or Diesel with CP	AC/DC CODAD	DC/DC Stea turbo-electric
Source: (Leslie, I.K., 1982)			

A.12 SUPPORT/MULTI-PURPOSE VESSELS

In addition to drill rigs, production platforms and tankers or LNG carriers, a large number of vessels providing either support or emergency/rescue or construction functions will be required to operate on the East Coast and in the Arctic. Their functions can be divided into sections as follows:

- general supplier, delivering provisions to remotely located exploration or production crews;
- anchor handling for floating exploration or production facilities or construction equipment;
- multi-role support, e.g., hospital, fire-fighting;
- support for diving systems;
- accommodation for construction, exploration or production crews;
- tugboat function for systems installation, barge pushing/pulling;
- floating airport for very remote exploration or production areas.

Most commonly used are the general support vessels which often integrate into one vessel system the general supply, standby, low load/short time tug and immediate rescue functions. Some also have diver/diving system support capability.

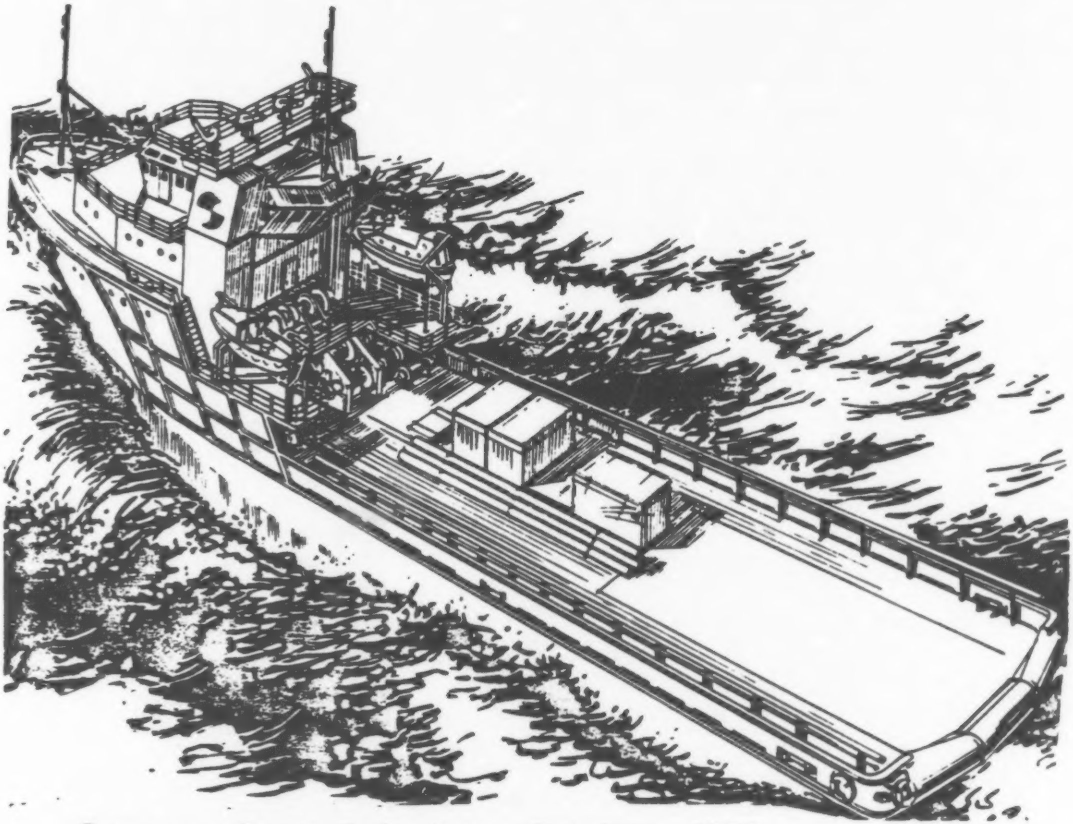
All of these vessels for use in the Canadian offshore and Arctic exploration and production areas will require protection against ice, for they will inevitably encounter ice-floes and often be the first one on site after thaw-out or the last ones to leave before freeze-up. Their hulls will likely require reinforcement to Class 3 for operation on the East Coast, and likely a higher class for Labrador. Support vessels in the Beaufort Sea and Arctic Islands operations require already ice Class 4 with a need for higher reinforcement by the time year-round operations commence.

Some of the more common vessels suitable for the Canadian offshore and Arctic environments include the Ulstein Vessel Class, a UT708 multi-functional supply vessel which has recently been ordered by Petro Canada for construction in a Vancouver shipyard. This vessel has typical dimensions of 67 m length, a deadweight of 2,000 tonnes, main propulsion of 10,500 h.p., a bollard pull of 120 tonnes and a speed of 17 knots, Figure A-26.

Vessels for the East Coast would range in the 8,000 h.p. level, with some reserve capability of up to 13,000 h.p. Hulls would be ice-strengthened to Class 2. The vessel length would be 64 m, with about 1,400 dead weight tonnage. (Peter, S.S. et al, 1981).

In the operations of remotely located North Sea fields, it has become common to provide special quarters for the crews off the production platform. The most widely used platform system for accommodation is semi-submersibles. Some early systems were converted drilling rigs, but it has become widely accepted that the accommodation rigs experience higher stress levels in the structurally sensitive areas than semi-submersible drilling rigs. (Stephen, R.R., 1982).

FIGURE A-26
UT708 MULTI-FUNCTIONAL SUPPLY VESSEL



Source: Ocean Industry - October, 1980.

Developed from the experience, mainly in the rough environmental conditions of the North Sea, the new breed of emergency support vessels is beginning to emerge, the first ones coming on stream in 1982. Differing in detailed specifications by the requirements of their owners, they all have in common the function to carry out work that does not fit the conventional activities of drill rigs and production platforms, and work that can be conducted from considerably smaller units. Typically, they are large semi-submersibles incorporating the functions of hospital, hyperbaric rescue, large cranes for work on other facilities, large general workshop capability for repair work, powerful fire-fighting capability based on water and foam, pollution clean-up facilities and support facilities for the larger saturation diving systems as well as other subsea machinery.

BNOC has its IoLair already in operation, while the Seaforth Maritime MSV is being readied for Shell.

As part of the support services required by offshore installations and operations, divers and diving systems play a very significant role. Installation, maintenance and repair of underwater structures have in the past increased the time required for the divers to stay underwater, and consequently, increased the diving system capabilities in terms of water depth, multitude of functions, degree of safety, extension of time for divers to work out of the chambers and number of crew, as well as convenience.

Canada has a history of development of a diving system which the Defence and Civil Institute of Environmental Medicine (DCIEM) of the Canadian Forces Research Establishment, developed a few years ago. Designed as a hyperbaric research facility, the system is capable of diving to 1700 m water depths.

Basically resembling a horizontal cylinder, divided into three compartments of 2.6 m internal diameter and about 8 m length for each of the three cylinders, the vessels were fabricated from ASTM A 516-72 Grade 70 steel plate sections and hemispherical heads. The cylindrical sections have a wall thickness of 150 mm. The heads were cold-rolled and of 85 mm thickness. Fabricated to Section VIII, Division 2 of the ASME Boiler and Pressure Vessel Code, all welds were radiographically inspected and the entire vessel was stress relieved.

While not necessarily representative for current and future commercial diving systems, this Canadian facility is a good example of the capabilities of the Canadian fabrication industry. (Fullerton, D.J., 1978).

A.13 VESSELS FOR ARCTIC MINING PROJECTS

While the hydrocarbon industry-related projects enjoy a high visibility, the mineral mining industry has slowly but steadily opened up the Arctic with its projects.

To install the processing equipment on location far remote from any industrial fabrication capability, it has become practice to build these process facilities in southern shipyards on to barges which are then pulled by tugboat to site. In most cases, the equipment will continue to stay on the barge which will either be bermed or moored. One such barge was the Arvik II used in Cominco's Polaris mine project on Little Cornwallis Island. All of the processing equipment, for a capacity of 2050 tonnes per day, is located on that one barge. It features a double hull of 138 m x 33 m x 4.8 m depth. A total of 2553 tonnes of mild steel were used in the building of the barge. Ice strengthening was done by a

25 mm thick belt on the outer shell made from Grade E steel. Additional strengthening and stiffening for ice loading by heavy pack ice was allowed, and limitations were imposed on deflections in the hull due to sea swell actions. An additional protection against ice and wave action during the tow was provided by a 2 m high reinforced continuous bulwark of steel, construction welded to the hull around the main deck as foundation for the super structure. (MacDonald, D., 1982).

A.14 VESSEL REPAIRS

For years the Canadian shipbuilding industry has considered the repair business one of its most lucrative revenue generators. In the recent past, several of the shipyards have undergone extensive reorganization and investment to concentrate more on the repair business. Repair work traditionally is dependent on the appropriate location close to heavily frequented harbours or shipping lanes and business is commonly compensated on the basis of effort expended in the repair job, as opposed to bidding the lowest price.

Table A-6 lists the tonnage used by one of the repair shops for a moderate amount of repair work during 1981. These repairs included mainly fishing vessels and those for general cargo. When the offshore activities on the East Coast or the Beaufort Sea gain momentum, repair work involving 25 mm thick plate and up will not necessarily increase the percentage of plate used. This will be so because the quality of the larger and more specialized vessels will be higher. They will also be designed to withstand greater impact and will therefore contract less damage.

TABLE A-6

ANNUAL TONNAGE FOR ONE REPAIR SHOP FOR 1981

PLATE THICKNESS IN INCHES		ANNUAL TONNAGE
½"		97
9/16"		5
5/8"		48
3/4"		52
7/8"		3
	Subtotal:	205
1"		16
1¼"		11
1½"		9
1 3/4"		.5
2"		4
2¼"		1
	Subtotal:	41.5
	Total:-	246.5

APPENDIX B

THICK STEEL PLATE REQUIREMENTS FOR TYPICAL EQUIPMENT

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: SUPPLY BOAT - 240'

FOR USE IN PROJECT: EAST COAST

SERVICE: GENERAL SUPPORT - PRODUCTION

REPRESENTATIVE SIZE, CAPACITY: 77m x 17m x 10m/ICE CLASS 2-3

STEEL PLATE TONNAGE

GRADE (ABS)	*THICKNESS RANGE (mm)*		
	25 - 37 (1" - 1½")	*38 - 50 (1½' - 2')*	*Over 50 (Over 2")*
E	100	100	
EH 36 MODIFIED	300		
LOW TEMPERATURE STEEL			

THICK PLATE STEEL CONTENT OF
OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: SEMI-SUBMERSIBLE DRILLING RIG

FOR USE IN PROJECT: EAST COAST - ALL LOCATIONS

SERVICE: OIL & GAS EXPLORATION WITH POTENTIAL FOR CONVERSION TO PRODUCT

REPRESENTATIVE SIZE, CAPACITY: 2 PONTOONS 100m x 12m x 8m

6 COLUMNS 10/8m OD, 33m LONG

BRAZING 2m OD, 200m LONG TOTAL

DECK CONNECTIONS 1350m^2

STEEL PLATE TONNAGE

GRADE (ABS)	*THICKNESS RANGE (mm)*		
	25 - 37 (1" - 1½")	*38 - 50 (1½' - 2')*	*Over 50 (Over 2")*
E			
EH 36 MODIFIED	1850	400	
LOW TEMPERATURE STEEL			

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: SEMI-SUBMERSIBLE PRODUCTION PLATFORM

FOR USE IN PROJECT: HIBERNIA FIELD

SERVICE: OIL PRODUCTION

REPRESENTATIVE SIZE, CAPACITY: 2 PONTOONS 130m x 16m x 10m

6 COLUMNS 15/11m OD, 22m HIGH

BRAZING STRUTS 2.5 OD, 300m TOTAL

DECK CONNECTIONS 2000m^2

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E EH 36 MODIFIED LOW TEMPERATURE STEEL	2350	2040	510

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: SEMI-SUBMERSIBLE

FOR USE IN PROJECT: HIBERNIA FIELD

SERVICE: OIL STORAGE

REPRESENTATIVE SIZE, CAPACITY: 2 PONTOONS 250m x 20m x 12m

10 COLUMNS 6 x 18m OD, 25m HIGH
4 x 13m OD, 22m HIGH
BRAZING STRUTS 2.5m OD, 400m TOTAL

DECK CONNECTIONS 3000m^2

STEEL PLATE TONNAGE

GRADE (ABS)	*THICKNESS RANGE (mm)*		
	25 - 37 (1" - 1½")	*38 - 50 (1½' - 2')*	*Over 50 (Over 2")*
E EH 36 MODIFIED LOW TEMPERATURE STEEL	4700	3850	950

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: OIL TANKER

FOR USE IN PROJECT: EAST COAST - HIBERNIA FIELD

SERVICE: OIL TRANSPORTATION SHUTTLE

REPRESENTATIVE SIZE, CAPACITY: 250m x 37m x 23m 100,000 DWT

CLASS 2-3 ICE-REINFORCED.

STEEL PLATE TONNAGE

GRADE (ABS)	*THICKNESS RANGE (mm)*		
	25 - 37 (1" - 1½")	*38 - 50 (1½' - 2')*	*Over 50 (Over 2")*
E	500		
EH36 MODIFIED	1500		
LOW TEMPERATURE STEEL			

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: STEEL JACKET OIL PRODUCTION PLATFORM

FOR USE IN PROJECT: GRAND BANKS - HIBERNIA

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 8 LEGS 200m, 2.5m OD

16 PILES 90m, 1.8m OD

16 MAJOR NODES 1000 T EACH

16 MINOR NODES 250 T EACH

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E			
EH36 MODIFIED	1460	12,400	
LOW TEMPERATURE STEEL	1000	10,000	

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: CONCRETE GRAVITY OIL PLATFORM

FOR USE IN PROJECT: GRAND BANKS - HIBERNIA

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 250m

DECK-STEEL, 12,000m^2

STEEL SKIRT

STEEL PLATE TONNAGE

GRADE (ABS)	*THICKNESS RANGE (mm)*		
	25 - 37 (1" - 1½")	*38 - 50 (1½' - 2')*	*Over 50 (Over 2")*
E			
EH36 MODIFIED	1000	1000	
LOW TEMPERATURE STEEL			

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: STEEL JACKET GAS PRODUCTION PLATFORM

FOR USE IN PROJECT: SCOTIA SHELF - SABLE ISLAND

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 4 LEGS, 8 PILES, 16 NODES
(250') (90') (1.5m OD)

ADD 15% TONNAGE FOR THE 350' PLATFORM

STEEL PLATE TONNAGE

GRADE (ABS)	*THICKNESS RANGE (mm)*		
	25 - 37 (1" - 1½")	*38 - 50 (1½' - 2')*	*Over 50 (Over 2")*
E	350	400	
EH36 MODIFIED	950	300	
LOW TEMPERATURE STEEL			

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: OIL TANKER CLASS 10

FOR USE IN PROJECT: BEAUFORT SEA

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 360m x 50m x 45m

200,000 DWT

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E	800	500	
EH36 MODIFIED	1500	600	
LOW TEMPERATURE STEEL	1500	3900	

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: SUPER DREDGE

FOR USE IN PROJECT: BEAUFORT SEA

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 210m x 35m

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E	600		
EH36 MODIFIED	400	1000	
LOW TEMPERATURE STEEL	700	1200	

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: ICEBREAKER/AML CLASS 4

FOR USE IN PROJECT: BEAUFORT/ARCTIC ISLANDS

SERVICE: SUPPORT/SUPPLY/GENERAL ACTIVITIES

REPRESENTATIVE SIZE, CAPACITY: 80m x 17m x 10m

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E	50		
EH36 MODIFIED	90		
LOW TEMPERATURE STEEL	270	80	

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: ICEBREAKER/AML CLASS 6

FOR USE IN PROJECT: BEAUFORT/ARCTIC ISLANDS

SERVICE: SUPPLY/SUPPORT/GENERAL ACTIVITIES

REPRESENTATIVE SIZE, CAPACITY: 100m x 22m x 15m

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E			
EH36 MODIFIED	180	130	
LOW TEMPERATURE STEEL	550	370	

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: PROCESS BARGE

FOR USE IN PROJECT: BEAUFORT SEA

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 200m x 60m

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E			
EH36 MODIFIED	310		
LOW TEMPERATURE STEEL			

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: **STORAGE BARGE**

FOR USE IN PROJECT: **BEAUFORT SEA**

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: **300m x 70m**

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E			
EH36 MODIFIED	430		

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: DRILL BARGE

FOR USE IN PROJECT: BEAUFORT SEA

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 150m x 30m

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E	130		
EH36 MODIFIED	580	210	
LOW TEMPERATURE STEEL	100	225	

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: ACCOMMODATION BARGE FOR CONSTRUCTION/OPERATION

FOR USE IN PROJECT: BEAUFORT SEA

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 150m x 30m

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E			
EH36 MODIFIED	210		

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: CAISSON TYPE ARTIFICIAL ISLAND

FOR USE IN PROJECT: BEAUFORT SEA (ESSO/GULF)

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 8,000 TONNES

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm) 25 - 37 (1" - 1½")	THICKNESS RANGE (mm) 38 - 50 (1½' - 2')	THICKNESS RANGE (mm) Over 50 (Over 2")
E			
EH36 MODIFIED	3,700		
LOW TEMPERATURE STEEL			

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: **ROUND DRILL SHIP**

FOR USE IN PROJECT: **BEAUFORT SEA**

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: **65m x 65m**

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E			
EH36 MODIFIED	**1620**		
LOW TEMPERATURE STEEL	**1160**		

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: LNG CARRIER - CLASS 7

FOR USE IN PROJECT: ARCTIC ISLANDS

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 375m x 42m x 40m

125,000m^3

STEEL PLATE TONNAGE

GRADE (ABS)	*THICKNESS RANGE (mm)*		
	25 - 37 (1" - 1½")	*38 - 50 (1½' - 2')*	*Over 50 (Over 2")*
E	100	100	
EH36 MODIFIED	1500	500	
LOW TEMPERATURE STEEL	1900	3400	

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: **LNG PLANT BARGE**

FOR USE IN PROJECT: **ARCTIC PILOT PROJECT (APP)**

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: **135m x 32m x 15m**

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E			
EH36 MODIFIED	200		
LOW TEMPERATURE STEEL			

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: LNG STORAGE BARGE

FOR USE IN PROJECT: ARCTIC PILOT PROJECT (APP)

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: 175m x 36m x 24m

STEEL PLATE TONNAGE

GRADE (ABS)	THICKNESS RANGE (mm)		
	25 - 37 (1" - 1½")	38 - 50 (1½' - 2')	Over 50 (Over 2")
E			
EH36 MODIFIED	250		
LOW TEMPERATURE STEEL			

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: **POLARIS 8 ICEBREAKER**

FOR USE IN PROJECT: **ARCTIC ISLANDS**

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: **194m x 32.2m x 18.75m**

STEEL PLATE TONNAGE

GRADE (ABS)	*THICKNESS RANGE (mm)*		
	25 - 37 *(1" - 1½")*	*38 - 50* *(1½' - 2')*	*Over 50* *(Over 2")*
E			
EH36 MODIFIED	**450**	**800**	
LOW TEMPERATURE STEEL	**550**	**1200**	

THICK PLATE STEEL CONTENT OF OFFSHORE STRUCTURES AND ARCTIC VESSELS

EQUIPMENT: POLARIS 10 ICEBREAKER

FOR USE IN PROJECT: ARCTIC ISLANDS

SERVICE:

REPRESENTATIVE SIZE, CAPACITY: GUESS 220m x 37m x 20m

STEEL PLATE TONNAGE

GRADE (ABS)	*THICKNESS RANGE (mm)*		
	25 - 37 (1" - 1½")	*38 - 50 (1½' - 2')*	*Over 50 (Over 2")*
E	500		
EH36 MODIFIED	500	500	
LOW TEMPERATURE STEEL	1000	2500	

APPENDIX C

THICK STEEL PLATE ORDERS BY PROJECT AND YEAR

THICK STEEL PLATE ORDERS FOR PROJECT: EAST COAST EXPLORATION

PAGE 1 *OF* 1

STEEL PLATE TONNAGE

YEAR	*EQUIPMENT*	*QUANTITY*	*GRADE E*		*EH 36 (Incl. Modif'd)*		*LOW TEMPERATURE STEEL*		*TOTAL TONNAGE PER YEAR*
			25-37mm	*38mm plus*	*25-37mm*	*38mm plus*	*25-37mm*	*38mm plus*	
1982	DRILLING SEMI	1			1850	400			2250
1983	SUPPLY BOATS	1	100	100	300				500
1984	DRILLING SEMI'S	2			3700	800			
	SUPPLY BOATS	2	200	200	600				5500
1986	DRILLING SEMI	1			1850	400			
	SUPPLY BOAT	1	100	100	300				2750
1989	DRILLING SEMI	1			1850	400			2250
	SUPPLY BOAT	1	100	100	300				500
TOTALS/SUBTOTALS:-			500	500	10750	2000			

THICK STEEL PLATE ORDERS FOR PROJECT: HIBERNIA OIL PRODUCTION

PAGE 1 OF 2

STEEL PLATE TONNAGE

YEAR	EQUIPMENT	QUANTITY	GRADE E		EH 36 (Incl. Modif'd)		LOW TEMPERATURE STEEL		TOTAL TONNAGE PER YEAR
			25-37mm	38mm plus	25-37mm	38mm plus	25-37mm	38mm plus	
1983	ACCOMODATION SEMI	1			1850	400			2250
1984	SUPPLY BOATS	2	200	200	600				1000
1985	PRODUCTION SEMI	1			2530	2540			
	STORAGE SEMI	1			4700	4800			
	TANKER	1	500		1500				
	SUPPLY BOATS	2	200	200	600				17570
1986	TANKER	1	500		1500				2000
1989	PRODUCTION SEMI	1			2530	2540			
	STORAGE SEMI	1			4700	4800			
	TANKERS	2	1000		3000				
	SUPPLY BOATS	2	200	200	600				19570
1992	PRODUCTION SEMI	1			2530	2540			
	STORAGE SEMI	1			4700	4800			
TOTALS/SUBTOTALS:-			2600	600	31340	22420			

THICK STEEL PLATE ORDERS FOR PROJECT: HIBERNIA OIL PRODUCTION

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STEEL PLATE TONNAGE

YEAR	EQUIPMENT	QUANTITY	GRADE E		EH 36 (Incl. Modif'd)		LOW TEMPERATURE STEEL		TOTAL TONNAGE PER YEAR
			25-37mm	38mm plus	25-37mm	38mm plus	25-37mm	38mm plus	
1992	TANKERS	2	1000		3000				
	SUPPLY BOATS	2	200	200	600				19570
1993	LNG PROC. SEMI	1			1850	400			
	LNG STORAGE SEMI	1			2530	2540			
	LNG CARRIER	2	1000		3000				
	SUPPLY BOATS	2	200	200	600				12320
1997	PROD. CONCRETE PL.	1			1000	1000			
	TANKERS	2	1000		3000				
	SUPPLY BOATS	2	200	200	600				7000
	TOTALS/SUBTOTALS:-		6200	1200	47520	26360			

THICK STEEL PLATE ORDERS FOR PROJECT: SCOTIA SHELF GAS PRODUCTION

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STEEL PLATE TONNAGE

YEAR	EQUIPMENT	QUANTITY	GRADE E		EH 36 (Incl. Modif'd)		LOW TEMPERATURE STEEL		TOTAL TONNAGE PER YEAR
			25-37mm	38mm plus	25-37mm	38mm plus	25-37mm	38mm plus	
1985	STEEL PLATFORM	1	350	400	950	300			3000
	SUPPLY BOATS	2	200	200	600				
1988	STEEL PLATFORM	1	350	400	950	300			3000
	SUPPLY BOATS	2	200	200	600				
1995	STEEL PLATFORM	1	400	460	1100	340			3300
	SUPPLY BOATS	2	200	200	600				
TOTALS/SUBTOTALS:-			1700	1860	4800	940			

THICK STEEL PLATE ORDERS FOR PROJECT: BEAUFORT SEA - DOME

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STEEL PLATE TONNAGE

YEAR	*EQUIPMENT*	*QUANTITY*	*GRADE E*		*EH 36 (Incl. Modif'd)*		*LOW TEMPERATURE STEEL*		*TOTAL TONNAGE PER YEAR*
			25-37mm	*38mm plus*	*25-37mm*	*38mm plus*	*25-37mm*	*38mm plus*	
1982	CONSTRUCTION BARGE	1			210				
	AML 6	1			180	130	550	370	
	SUPPLY BOAT	1	100	100	300				
	DREDGE	1	600		400	1000	700	1200	5840
1983	AML 4	1	50		90		270	80	
	DRILLING BARGE	1	130		580	210	100	225	
	SUPPLY BOAT	1	100	100	300				2235
1984	AML 4	1	50		90		270	80	
	SUPPLY BOAT	1	100	100	300				
	DREDGE	1	600		400	1000	700	1200	4890
1985	TANKER	1	800	500	1500	600	1500	3900	8800
1986	TANKER	1	800	500	1500	600	1500	3900	
	PROCESS BARGE	1			310				
	STORAGE BARGE	1			430				
	AML 6	1			180	130	550	370	
	AML 4	1	50		90		270	80	
	SUPPLY BOAT	1	100	100	300				
TOTALS/SUBTOTALS:-			3480	1400	7160	3670	6410	11405	

THICK STEEL PLATE ORDERS FOR PROJECT: BEAUFORT SEA - DOME

STEEL PLATE TONNAGE

YEAR	EQUIPMENT	QUANTITY	GRADE E		EH 36 (Incl. Modif'd)		LOW TEMPERATURE STEEL		TOTAL TONNAGE PER YEAR
			25-37mm	38mm plus	25-37mm	38mm plus	25-37mm	38mm plus	
1986	OPERATIONS BARGE	1			210				
	DREDGE	1	600		400	1000	700	1200	15870
1987	TANKER	1	800	500	1500	600	1500	3900	
	DRILLING BARGE	1	130		580	210	100	225	
	ROUND DRILLSHIP	1			1620		1160		
	CONSTRUCTION BARGE	1			210				13035
1988	TANKER	1	800	500	1500	600	1500	3900	
	STORAGE BARGE	1			430				
	PROCESS BARGE	1			310				
	DRILLING BARGE	1	130		580	210	100	225	
	AML 4	1	50		90		270	80	
	SUPPLY BOAT	1	100	100	300				11775
1989	TANKER	1	800	500	1500	600	1500	3900	
	STEEL CAISSON	1			3700				
	DRILLING BARGE	1	130		580	210	100	225	
	ROUND DRILLSHIP	1			1620		1160		
	SUPPLY BOAT	1	100	100	300				
TOTALS/SUBTOTALS:-			3640	1700	15430	3430	8090	13655	

THICK STEEL PLATE ORDERS FOR PROJECT: BEAUFORT SEA - DOME

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STEEL PLATE TONNAGE

YEAR	*EQUIPMENT*	*QUANTITY*	*GRADE E*		*EH 36 (Incl. Modif'd)*		*LOW TEMPERATURE STEEL*		*TOTAL TONNAGE PER YEAR*
			25-37mm	*38mm plus*	*25-37mm*	*38mm plus*	*25-37mm*	*38mm plus*	
1989	OPERATIONS BARGE	1			210				
	DREDGE	1	600		400	1000	700	1200	21135
1990	TANKER	1	800	500	1500	600	1500	3900	
	AML 4	1	50		90		270	80	
	SUPPLY BOAT	1	100	100	300				9790
1991	ROUND DRILLSHIP	1			1620		1160		
	SUPPLY BOAT	1	100	100	300				3280
1992	TANKER	1	800	500	1500	600	1500	3900	
	AML 4	1	50		90		270	80	
	SUPPLY BOAT	1	100	100	300				9790
1993	TANKER	1	800	500	1500	600	1500	3900	
	OPERATIONS BARGE	1			210				9010
1994	SUPPLY BOAT	1	100	100	300				
	STEEL CAISSON	1			3700				4200
1995	TANKER	1	800	500	1500	600	1500	3900	
	PROCESS BARGE	1			310				
	STORAGE BARGE	1			430				9540
TOTALS/SUBTOTALS:-			4300	2400	14260	3400	8400	16960	

THICK STEEL PLATE ORDERS FOR PROJECT: BEAUFORT SEA - DOME

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STEEL PLATE TONNAGE

YEAR	EQUIPMENT	QUANTITY	GRADE E		EH 36 (Incl. Modif'd)		LOW TEMPERATURE STEEL		TOTAL TONNAGE PER YEAR
			25-37mm	38mm plus	25-37mm	38mm plus	25-37mm	38mm plus	
1996	AML 4	1	50		90		270	80	
	SUPPLY BOAT	1	100	100	300				990
1997	DRILLING BARGE	1	130		580	210	100	225	
	AML 4	1	50		90		270	80	1735
1998	TANKER	1	800	500	1500	600	1500	3900	
	SUPPLY BOAT	1	100	100	300				9300
TOTALS/SUBTOTALS:-			1230 12650	700 6200	2860 39710	810 11310	2140 25040	4285 46305	

THICK STEEL PLATE ORDERS FOR PROJECT: **BEAUFORT - ESSO/GULF**

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STEEL PLATE TONNAGE

YEAR	EQUIPMENT	QUANTITY	GRADE E		EH 36 (Incl. Modif'd)		LOW TEMPERATURE STEEL		TOTAL TONNAGE PER YEAR
			25-37mm	38mm plus	25-37mm	38mm plus	25-37mm	38mm plus	
1983	SUPPLY BOATS	2	200	200	600				1000
1984	STEEL CAISSON	1			3700				
	AML 6	1			180	130	550	370	4930
1986	SUPPLY BOATS	2	200	200	600				
	TANKER	1	800	500	1500	600	1500	3900	
	STORAGE BARGE	1			430				
	PROCESS BARGE	1			310				
	OPERATIONS BARGE	1			210				
	AML 4	1	50		90		270	80	11240
1988	ROUND DRILLSHIP	1			1620		1160		2780
TOTALS/SUBTOTALS:-			1250	900	9240	730	3480	4350	

THICK STEEL PLATE ORDERS FOR PROJECT: **BEAUFORT - ESSO/GULF**

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STEEL PLATE TONNAGE

YEAR	EQUIPMENT	QUANTITY	GRADE E		EH 36 (Incl. Modif'd)		LOW TEMPERATURE STEEL		TOTAL TONNAGE PER YEAR
			25-37mm	38mm plus	25-37mm	38mm plus	25-37mm	38mm plus	
1990	TANKER	1	800	500	1500	600	1500	3900	
	STORAGE BARGE	1			430				
	SUPPLY BOAT	1	100	100	300				9730
1992	OPERATIONS BARGE	1			210				210
1994	TANKER	1	800	500	1500	600	1500	3900	
	PROCESS BARGE	1			310				
	AML 4	1	50		90		270	80	9600
1996	STORAGE BARGE	1			430				
	SUPPLY BOATS	2	200	200	600				1430
1998	TANKER	1	800	500	1500	600	1500	3900	
	PROCESS BARGE	1			310				9110
TOTALS/SUBTOTALS:-			2750	1800	7180	1800	4770	11780	
			4000	2700	16420	2530	8250	16130	

THICK STEEL PLATE ORDERS FOR PROJECT: ARCTIC PILOT PROJECT (LNG)

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STEEL PLATE TONNAGE

YEAR	EQUIPMENT	QUANTITY	GRADE E		EH 36 (Incl. Modif'd)		LOW TEMPERATURE STEEL		TOTAL TONNAGE PER YEAR
			25-37mm	38mm plus	25-37mm	38mm plus	25-37mm	38mm plus	
1983	ICEBREAKER CL.6	1			180	130	550	370	
	SUPPLY BOATS	2	200	200	600				
	CONSTRUCTION BARGE	1			210				2440
1984	PROCESS BARGE	1			200				
	STORAGE BARGES	2			500				
	SUPPLY BOATS	2	200	200	600				
	ICEBREAKER CL.4	1	50		90		270	80	
	OPERATIONS BARGE	1			210				2400
1985	LNG CARRIERS	2	200	200	3000	1000	3800	6800	
	SUPPLY BOATS	2	200	200	600				16000
TOTALS/SUBTOTALS:-			850	800	6190	1130	4620	7250	

THICK STEEL PLATE ORDERS FOR PROJECT: KING CHRISTIAN ISLAND LNG

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STEEL PLATE TONNAGE

YEAR	EQUIPMENT	QUANTITY	GRADE E		EH 36 (Incl. Modif'd)		LOW TEMPERATURE STEEL		TOTAL TONNAGE PER YEAR
			25-37mm	38mm plus	25-37mm	38mm plus	25-37mm	38mm plus	
1988	ICEBREAKER CL.6	1			180	130	550	370	
	SUPPLY BOATS	2	200	200	600				
	CONSTRUCTION BARGE	1			210				2440
1989	LNG PROCESS BARGES	2			400				
	LNG STORAGE BARGES	4			1000				
	SUPPLY BOATS	2	200	200	600				
	OPERATIONS BARGE	1			210				2610
1990	LNG CARRIERS	2	200	200	3000	1000	3800	6800	
	SUPPLY BOATS	2	200	200	600				16000
1991	LNG CARRIER	1	100	100	1500	500	1900	3400	7500
1994	LNG CARRIER	1	100	100	1500	500	1900	3400	
	ICEBREAKER CL.6	1			180	130	550	370	
	SUPPLY BOAT	1	100	100	300				9630
1995	LNG CARRIERS	2	200	200	3000	1000	3800	6800	
	PROCESS BARGES	2			400				
	STORAGE BARGES	4			1000				16400
TOTALS/SUBTOTALS:-			1300	1300	14680	3260	12500	21140	

THICK STEEL PLATE ORDERS FOR PROJECT: ARCTIC MINING PROJECTS

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STEEL PLATE TONNAGE

YEAR	EQUIPMENT	QUANTITY	GRADE E		EH 36 (Incl. Modif'd)		LOW TEMPERATURE STEEL		TOTAL TONNAGE PER YEAR
			25-37mm	38mm plus	25-37mm	38mm plus	25-37mm	38mm plus	
1984	PROCESS/STORAGE BARGES	2			600				600
1986	POLARIS 8 ICE-BREAKER	1			450	800	550	1200	3000
1988	PROCESS/STORAGE BARGES	2			600				600
1992	PROCESS/STORAGE BARGES	2			600				600
1994	POLARIS 10 ICE-BREAKER	1	500		500	500	1000	2500	5000
1996	PROCESS/STORAGE BARGES	2			600				600
TOTALS/SUBTOTALS:-			500		3350	1300	1550	3700	